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FRICTION LOSSES IN THIRTY-INCH STEEL PIPE LINED WITH BITUMASTIC ENAMEL

By Farley Gannett and J. D. Carpenter

(Of Gannett, Seelye & Fleming, Engineers, Inc., Harrisburg, Penna.)

In the summer and fall of 1932 a steel pipe line, ten miles long, with an inside diameter of 30 inches was laid in Schuylkill County, Pennsylvania, to furnish water from the Still Creek Reservoir to the mining towns in the Panther Creek Valley. This line was built for the Panther Valley Water Company, a subsidiary of the Lehigh Coal and Navigation Company, principally to furnish fresh water to the Coal Company for washing anthracite coal. So far as is known this is the first coal company to wash its coal entirely with potable water, and the result is a very clean and attractive coal.

Water was required by the consumers of the Panther Valley Water Company in definite quantities and at given elevations or pressures and as the flow is entirely by gravity, the loss of head due to friction had to be carefully considered, as it affected the size and consequently the cost of the pipe. The original design called for a line half 36-inch and half 30-inch inside diameter with an expected coefficient of friction of 100. After studying pipe sizes, costs, and probable friction losses, it was decided that the most economical and practical plan was to use all 30-inch steel pipe and to coat it on the inside with a $\frac{3}{32}$-inch lining of Wailes Dove-Hermiston bitumastic enamel. A coefficient "C" of 140 was expected and the carrying capacity and friction losses of the line were worked out on that basis.

In test, under a maximum flow of 12,000,000 g.p.d. the pipe line gave a coefficient "C" of 143.5 to 145.6.

DESCRIPTION OF PROJECT

So far as the writer knows this is the first large steel water line to be welded, Dresser-coupled, and at the same time lined with a protective and friction-reducing material.

The physical characteristics of this line will probably be of interest to anyone wishing to compare or estimate results from lines which they may have under consideration and for this reason, a general description of the pipe line is here given.

CHARACTER OF COUNTRY

The first five miles of the line were laid down the East side of the Little Schuylkill River valley, crossing a number of streams and many hills and gullies. The second half of the line followed, for the greater part, the State Highway, paralleling the Panther Creek Valley and here the grades were much easier and the bends fewer.

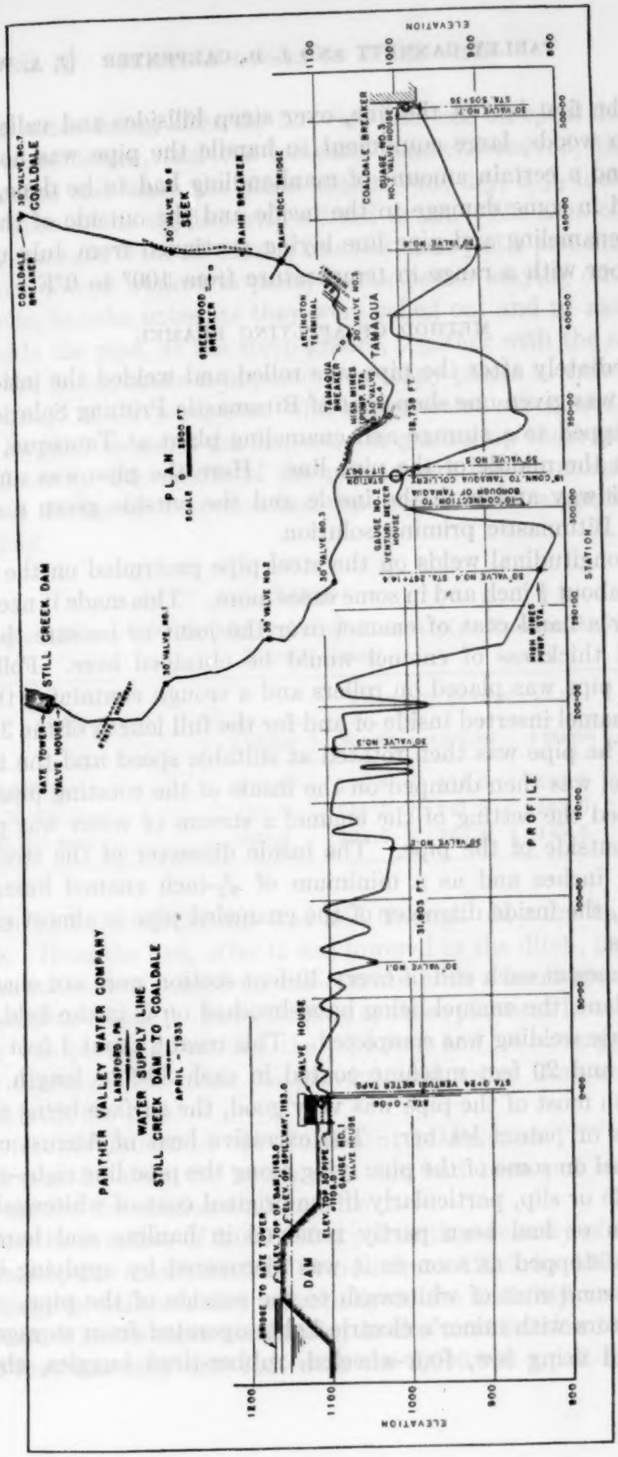
On the whole line there were 85 special horizontal bends with a maximum curvature of 70° 40′ and a minimum of 4° 3′. There were also 81 vertical bends with a maximum of 40° 36′. These bends were built of $\frac{3}{8}$-inch steel plate welded usually in 4 or 5 sections with a center radius of 6 to 10 feet.

The profile in figure 1 gives a general idea of the line. There were 51 air valves at high points and a corresponding number of blow-offs or drains, as it is planned to drain and inspect the line when convenient.

DETAILS OF LINE CONSTRUCTION

The steel pipe was shipped from the mill in 30 foot lengths, with one longitudinal weld. In the field three and occasionally four of these lengths were welded together and lowered into the ditch where a joint was made with a similar section by means of a bolted Dresser coupling with rubber gaskets. Bends of 3° could be made with the Dresser couplings. In many places only 60 feet (two sections of pipe) could be welded together before it was necessary to use another special bend.

Along the line were seven 30-inch gate valves and 48 manholes. There were also approximately 100 additional connections to the line for air valves, drains and a few connections to other piping systems.



PANTHER VALLEY WATER COMPANY
WATER SUPPLY LINE
STILL CREEK DAM TO COALDALE
PLAN
PROFILE
STILL CREEK DAM
TAMAQUA
COALDALE
SEEK
ELEVATION

FIG. 1

On the first half of the line, over steep hillsides and valleys and through woods, large equipment to handle the pipe was not practical, and a certain amount of manhandling had to be done, which resulted in some damage to the inside and the outside of the pipe.

The enameling and pipe line laying continued from July until in December with a range in temperature from 100° to 0°F.

METHOD OF APPLYING ENAMEL

Immediately after the pipe was rolled and welded the inside and outside was given one shop coat of Bitumastic Priming Solution and then shipped to a storage and enameling plant at Tamaqua, which is about the middle of the pipe line. Here the pipe was unloaded on a skidway and both the inside and the outside given a second coat of Bitumastic priming solution.

The longitudinal welds on the steel pipe protruded on the inside usually about $\frac{1}{8}$ inch and in some cases more. This made it necessary to apply a hand coat of enamel over the joint to be sure that the required thickness of enamel would be obtained here. Following this the pipe was placed on rollers and a trough containing the hot liquid enamel inserted inside of and for the full length of the 30-inch pipe. The pipe was then rotated at suitable speed and the trough of enamel was then dumped on the inside of the rotating pipe. To help speed the setting of the enamel a stream of water was played on the outside of the pipe. The inside diameter of the steel pipe was $30\frac{1}{4}$ inches and as a minimum of $\frac{3}{32}$-inch enamel lining was required, the inside diameter of the enameled pipe is almost exactly 30 inches.

Six inches at each end of every 30-foot section were not enameled at the plant, the enamel being hand-brushed on it in the field, after the electric welding was completed. This meant about 1 foot hand-brushed and 29 feet machine coated in each 30-foot length. The enamel on most of the pipe was very good, the surface being almost like glass or patent leather. The excessive heat of August caused the enamel on some of the pipe lying along the pipe line right-of-way to wrinkle or slip, particularly if the original coat of whitewash had been thin or had been partly removed in hauling and handling. This was stopped as soon as it was discovered by applying in the field a second coat of whitewash to the outside of the pipe.

Inspectors with miner's electric lights operated from storage batteries and using low, four-wheeled, rubber-tired buggies, checked

over the inside lining after the line was laid and on spots damaged during construction, had the loosened enamel removed, the pipe prime-coated and when the prime coating was dry, a $\frac{3}{32}$-inch finish coat of enamel was applied with a hand brush. The area of inside enamel, damaged from all causes, was less than $\frac{1}{2}$ of 1 percent. The inspectors always worked in pairs, one inspector staying outside at a manhole, to take notes, as they were called out and to assist the man inside the pipe, as the steep grades, together with the smoothness of the lining, made it impossible in many places to crawl uphill on the inside of the pipe, even with rubber-soled shoes, and a rope had to be used to assist the inspector in getting up these grades.

All places on the outside of the pipe, where the bitumastic solution was damaged were touched up before final assembly and backfilling.

TABLE 1

Values of coefficient "C" for 50,700 feet of 30-inch pipe lined with Bitumastic Enamel lining

LENGTH	DAILY RATE OF FLOW—G.P.D.				
	2,160,000	4,084,000	8,165,000	9,994,000	12,093,000
First 31,900 feet	123.9	135.8	144.6	143.6	143.5
Second 18,800 feet	145.5	144.5	147.3	143.5	145.6
Total 50,700 feet	130.8	139.6	145.8	143.5	143.4

About $1\frac{1}{2}$ miles of the line was laid through old culm banks and cinders. Here the line, after it was lowered in the ditch, but before final assembly, was coated on the outside with a hand-brushed coat of Bitumastic enamel. In backfilling at these places at least 6 inches of clay was placed all around the pipe first and, in swampy places, proper drainage was made, to prevent acid water from coming in contact with the pipe.

The test to determine the Coefficient of Friction "C" was run several months after the entire pipe line had been put in service. These results are summarized in table 1.

Under the low flow of 2,000,000 g.p.d. with a velocity of 0.68 foot per second, the coefficient "C" varies from 123.9 to 145.5. This wide range in values is due principally to the inability to measure the pressure losses more accurately, as the total friction loss in the 50,000 feet was only 3.09 feet with the 2,000,000 g.p.d. flow.

METHOD OF MEASURING WATER

Simplex Venturi meters, 30" x 12", are installed at each end of the line; one at the Valve House below the dam, and the other at Coaldale at the far end of the line. For two months the master meter at the Valve House read within 1 per cent of the total of all the meters through which water is sold, so that there is very little error in the setting or reading of the master meter. During the test, which was made on a Sunday, about 4,000 gallons were drawn from the line by one consumer. From 9:25 a.m. until 12:45 p.m. the total water recorded past the master meter at the dam was 1,039,000 gallons, while the meter at Coaldale passed 1,036,000 gallons in the same time interval. Rather than use the indicated rate of flow the actual water passed through the meter was used to compute the rate of flow.

LOCATION OF PRESSURE GAUGES

Gauge no. 1 was located in the Valve House, 600 feet downstream from the intake tower in the reservoir, and 30 feet upstream from the Venturi meter through which the water was first measured. The measuring point for pipe line length was the downstream end of the Venturi meter, and the loss of head through the Venturi meter is deducted to give the net pressure drop in the line itself.

Gauge no. 2 was located in the Tamaqua Colliery Meter House, which, in turn is located on the 16-inch line serving Tamaqua Colliery, which takes off from the 30-inch line 31,900 feet from the Venturi meter at the dam. This 16-inch line to the Colliery was quiet during the period of the test.

Gauge no. 3 was located on the 30-inch line at Coaldale; the line to the gauge being taken off from the throat of the 30" x 12" Venturi meter. This made it necessary to deduct from the pressure loss, the head or pressure lost in the first half, or to the throat of the Venturi meter. The losses used in this computation were checked by the Simplex Meter Company.

READINGS

Pressure gauges calibrated the day before the test were installed at each reading point. In addition to these pressure gauges, pressure recording gauges are also installed as permanent equipment at Tamaqua and at Coaldale. At the dam the pressure drop is so

small that a pressure recording gauge would give no information of value, and the only gauge used here was a 30-pound test gauge.

Two men stationed at the dam, at Tamaqua, and at Coaldale, took readings each minute of the indicated rate of flow and pressure, and every five minutes of the total flow through the meter. The measured flow, which has been used, gives a coefficient "C" from 1 to 2 points higher than given by the indicated rate of flow.

TABLE 2

Still Creek pipe line test. 30-inch I.D.—50,700 feet long

TIME	TOTAL GALLONS THROUGH METER	MINUTES	AVERAGE RATE OF FLOW, M.G.D.	STILL CREEK AND COALDALE AVERAGE
Still Creek Valve House				
9:20 to 10:00 a.m.	114,000	40	4,104,000	
10:05 to 10:40 a.m.	197,000	35	8,104,000	
10:50 to 11:30 a.m.	280,000	40	10,080,000	
11:35 to 12:00 noon	210,000	25	12,096,000	
12:10 to 12:20 p.m.	15,000	10	2,160,000	
Coaldale Meter House				
9:20 to 10:00 a.m.	113,000	40	4,068,000	4,086,000
10:05 to 10:40 a.m.	200,000	35	8,228,000	8,166,000
10:50 to 11:30 a.m.	270,000	40	9,900,000	9,990,000
11:35 to 12:00 noon	210,000	25	12,096,000	12,096,000
12:10 to 12:20 p.m.	14,500	10	2,088,000	2,124,000

Average Pressure (in Pounds)

TIME	DAM	TAMAQUA	COALDALE
9:20 to 10:00 a.m.	8.20	41.08	62.46
10:05 to 10:40 a.m.	8.14	35.0	51.69
10:50 to 11:30 a.m.	7.90	30.86	44.33
11:35 to 12:00 noon	7.75	25.34	34.76
12:10 to 12:20 p.m.	8.24	42.83	65.50

A summary of the flow readings and pressure readings is given in table 2.

Charts

The discharge of water through the pipe line was regulated through the openings at the far end of the line, beyond the second 30- x 12-inch meter. Sufficient discharge points were available so that

TABLE 3

Flow tests on water supply line from Still Creek Dam to Coaldale

Panther Valley Water Company, Lansford, Penna.

30 $\frac{3}{16}$-inch steel pipe electrically welded on longitudinal seams with dresser couplings and $\frac{3}{32}$-inch Bitumastic lining.

	DAILY RATE OF FLOW IN GALLONS				
	2,160,000	4,084,000	8,165,000	9,994,000	12,093,000
Gauge readings in pounds:					
1. Valve House at dam, equated to flow	8.24	8.20	8.00	7.90	7.75
2. Tamaqua Colliery	42.83	41.08	35.00	30.86	25.34
3. Coaldale Colliery	65.50	62.50	51.70	44.30	34.80
Gauge readings in feet:					
4. Valve House at dam	19.03	18.94	18.48	18.25	17.90
5. Tamaqua Colliery	98.94	94.89	80.85	71.29	58.53
6. Coaldale Colliery	151.31	144.37	119.43	102.33	80.39
Pressure drop in feet:					
7. At Valve House	0.03	0.12	0.58	0.81	1.16
8. At Tamaqua Colliery	2.24	6.29	20.33	29.89	42.65
9. At Coaldale Colliery	3.46	10.40	35.34	52.44	74.38
10. Between Gauges at Tamaqua Colliery and Coaldale Colliery	1.22	4.11	15.01	22.55	31.73
Coefficient of friction "C"—between Valve House and Tamaqua Colliery—distance 31,900 feet:					
11. Pressure drop in feet at Tamaqua Colliery	2.24	6.29	20.33	29.89	42.65
12. Less loss of head between dam and Valve House	0.03	0.12	0.58	0.81	1.16
13. Less loss of head through 30-inch x 12-inch Venturi tube at Valve House	0.06	0.20	0.71	1.04	1.52
14. Net pressure drop in feet	2.15	5.97	19.04	28.04	39.97
15. Velocity in feet per second "V"	0.680	1.280	2.573	3.147	3.8102
16. Coefficient of friction "C"	123.9	134.3	144.3	143.2	143.5

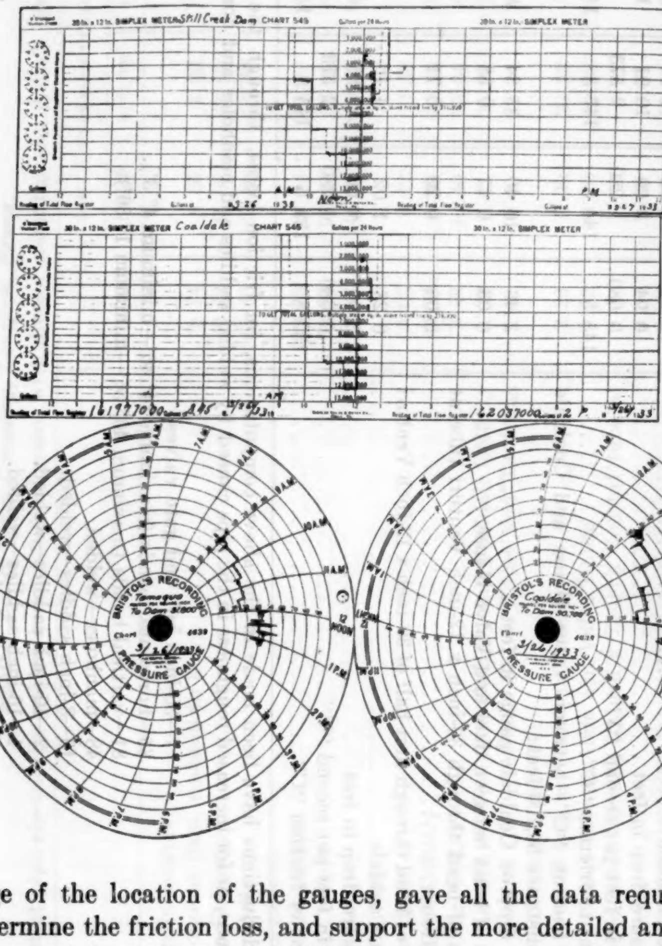
Coefficient of friction "C"—between Tamaqua Colliery and Coaldale

Coefficient of friction "C"—between Tamaqua Colliery and Coaldale Colliery—distance 18,800 feet:					
17. Pressure drop in feet	1.22	4.11	15.01	22.55	31.73
18. Less loss of head through first half of 30-inch x 12-inch Venturi tube at Coaldale	0.28	1.02	4.10	6.00	8.80
19. Net pressure drop in feet	0.94	3.09	10.91	16.55	22.93
20. Velocity in feet per second "V"	0.680	1.280	2.573	3.147	3.8102
21. Coefficient of friction "C"	145.5	144.5	147.3	143.5	145.6
Coefficient of friction "C"—between Valve House and Coaldale Colliery—distance 50,700 feet:					
22. Pressure drop on Coaldale gauge in feet	3.46	10.40	35.34	52.44	74.38
23. Less loss of head between dam and Valve House	0.03	0.12	0.58	0.81	1.16
24. Less loss of head through 30-inch x 12-inch Venturi tube at Valve House	0.06	0.20	0.71	1.04	1.52
25. Less loss of head through first half of 30-inch x 12-inch Venturi tube at Coaldale	0.28	1.02	4.10	6.00	8.80
26. Net pressure drop in feet	3.09	9.06	29.95	44.59	62.90
27. Velocity in feet per second "V"	0.680	1.280	2.573	3.147	3.8102
28. Coefficient of friction "C"	130.8	139.6	145.8	143.5	144.3

Note—No deductions have been made in the above computations, for friction losses, through the following list of valves and bends, or for increased roughness in the pipe caused by welded saddles and manholes and bosses for air valves and drains.

7—30-inch hub end gate valves.
85—horizontal bends (maximum 74° 40′—minimum 4° 3′).
81—vertical bends (maximum 40° 36′—minimum 1° 36′).
48—manholes—welded.
19—8-inch saddles—welded.
2—10-inch saddles—welded.
4—16-inch saddles—welded.
1—18-inch saddle—welded.
38—2-inch drains—tapped in welded boss.
3—2-inch air valves tapped in welded boss.
49—¾-inch air valves tapped in welded boss.

almost any rate of flow up to 12,000,000 g.p.d. could easily be obtained and held with reasonable accuracy. This was clearly shown on the Venturi meter chart taken at Coaldale, together with a similar chart for the meter at the dam, and pressure recording charts at Tamaqua and at Coaldale. These charts, together with a knowledge of the location of the gauges, gave all the data required to determine the friction loss, and support the more detailed and more accurate information obtained by the one-minute readings, both of discharge and pressure, that were taken throughout the test, which extended from 9:15 a.m. until 12:30 p.m. on March 26, 1933. After the test, as planned had been completed, an attempt was made to get readings at the 6,000,000 and 5,000,000 g p.d. rate, but due to



telephone failure, only partial records were obtained, which gave no definite conclusions.

WATER LEVEL IN RESERVOIR

During the test no change occurred in the elevation of the water in the reservoir. The storage in the reservoir at the time of the test was approximately 350,000,000 gallons and the 1,000,000 gallons used in making this test were about equal to the water flowing into the reservoir.

RECORDS

A detailed summary of the records taken and the results obtained is given in table 3.

This test was made possible through the courtesy of George M. Roads, Jr., Superintendent of the Panther Valley Water Company, and the writer wishes to express his appreciation of the coöperation and help received from Mr. Roads and his men during the running of this test.

SELECTION OF PUMPING EQUIPMENT FOR NEW SPRINGWELLS STATION AT DETROIT

By William C. Rudd

(*Assistant Engineer-Power, Department of Water Supply, Detroit, Mich.*)

The Springwells Station at Detroit consists of raw water or low lift pumping plant, filtered water or high lift pumping plant, power plant, and filter plant. This plant is designed for ultimate capacity of 206 m.g.d., average day, with present capacity of 120 m.g.d. The ultimate maximum day capacity is 280 and maximum hour capacity is 380 m.g.d.

The filter plant and pumping plant were placed in partial operation in October, 1931. This plant is a part of the additional water supply project for Detroit, which was first planned in 1919 and approved by the Board of Water Commissioners in 1924. The engineering organization was started in 1925 and construction work on the project substantially completed in 1931.

The additional water supply project consists of a new intake in the Detroit River and about twelve miles of concrete tunnel from the intake to the new Springwells Station, the tunnel varying in size from 15½ to 12 feet, inside diameter, and the plant and equipment as above mentioned.

Springwells Station is situated in the west central part of Detroit and is located in about the center of the distribution district which it is intended to serve.

This paper is an abstract of an article entitled "Selecting Pumping Units for Water Works Service," prepared by Mr. Louis E. Ayres, Consulting Engineer of Ann Arbor, Michigan, and the author, with especial reference to selection of the type of equipment and adapting motor driven centrifugals to metropolitan requirements.

The pumping plant as designed and constructed consists of the following motor driven centrifugal pumps:

Low lift plant (raw water pumps)

NUMBER	M.G.D.	HEAD, FEET
2	7.2	55
2	30	50
3	60	50
3	60	60

Total—10 units.
Total rated capacity—435 m.g.d.
Maximum day demand—280 m.g.d. (ultimate).

High lift plant (filter water distribution pumps)

NUMBER	M.G.D.	HEAD, FEET
2	30	200
2	40	130
4	40	200
2	50	130
2	50	150

Total—12 units.
Total rated capacity—500 m.g.d.
Maximum hour demand—370 m.g.d. (1940 condition).

Both plants

Total units	22 (present)
Total units	26 (future)
Total rated pump capacity	935 m.g.d. (present)
Total rated pump capacity	1115 m.g.d. (future)

TYPES AND FACTORS CONSIDERED

The types of equipment considered in these studies were:

1. Plunger pumps, driven by triple expansion engines:
2. Centrifugal pumps driven by:
   (a) Steam turbines.
   (b) Electric motors, both A.C. and D.C. and constant and variable speed.
   (c) Water turbines (low lift pumps only).

Three factors were kept in mind, as follows:

1. Adaptability;
2. Reliability;
3. Cost.

Under adaptability, account was taken of the relative ease and economy with which considerable variations in load and head, arising out of changes in water consumption, daily, throughout a year and over a period of years, could be met.

Under reliability such matters were weighed as plant location, whether near to reliable source of power; pump placement, whether at or near ground surface.

Cost became a determining factor only when other essential requirements had been met.

PRECEDENTS

Prior to 1923, all water pumping in Detroit had been done with plunger pumps, driven by reciprocating steam engines at the Water Works Park Station, located in the southeastern section of Detroit. At the time of the beginning of the studies and reports in 1919, there were in service and contemplated a total capacity, in pumping engines, of 378 m.g.d.

In 1923, a low lift pumping station, in connection with the new Water Works Park Filtration Plant, went into operation containing five motor driven centrifugal pumps with total rated capacity of 465 m.g.d. In 1926 steam pumping engines Nos. 1 and 2 at Water Works Park Station were replaced by motor driven centrifugal pumps of 140 million gallons combined daily capacity. In 1928 steam pumping engine No. 3 was replaced by a 40 m.g.d. motor driven centrifugal pump; and in 1930 a second 40 m.g.d. motor driven centrifugal pump was installed. With these changes accomplished, motor driven centrifugal pumps made up 40 percent of the total pumping capacity of 500 m.g.d. contained in the two Water Works Park distribution stations.

Although the policy of the Water Department up until 1924 was to distribute water with triple-expansion steam pumping, since that time *all* new units, including all pumps in the new Springwells Station, have been motor driven centrifugal pumps.

THE CONSULTANT'S REPORTS

Several consulting engineers recommended that steam turbine driven centrifugal pumps be used for *service* pumping, that is, for pumping into the distribution system, and motor driven centrifugal pumps for low lift pumping, supplying filter plants.

In the proposed Lake Huron project, which contemplated a 400

m.g.d., 375 feet head pumping station, located near the lower end of Lake Huron, it was proposed that a steam generating plant be provided in connection with a pumping plant. Such a proposal clearly indicated a major emphasis on reliability.

Of the two reports submitted, proposing Lake St. Clair as a source of supply, one consulting engineer emphasized dependability as the chief element to be considered in deciding the type of equipment. The other report stressed such elements as ease with which coal could be delivered, flexibility to meet hourly variations in water consumption, and cost.

In one report, which contemplated a filter plant on an artificial island in Lake St. Clair, motor driven centrifugal pumps were proposed. All other pumping was to be done by steam driven pumps, with turbine driven centrifugals recommended, although the door was not closed on the reciprocating pump.

The other report, which contemplated a Lake St. Clair supply, through an intake crib and an island filtration plant, proposed in the way of equipment:

(1) At the filtration plant—motor operated centrifugal pumps—on account of its more remote location and in order to eliminate the necessity for large and constant deliveries of coal.

(2) At the distribution pumping stations where service pumpage will fluctuate at all times to conform to hourly rates of consumption, steam turbine driven centrifugal pumps in order to provide for that flexibility essential to such service.

In the report of George H. Fenkell, General Manager of the Department of Water Supply, submitted in September, 1923, the Detroit River near the head of Belle Isle was recommended as a source of supply. The construction and operating costs involved in pumping stations were presented, in considerable detail, on

(1) Motor driven centrifugal pumps.

(2) Steam turbine driven centrifugal pumps.

(3) Triple-expansion steam pumping engines.

The conclusions as to cost were that, under Detroit conditions, where the hourly peak, plus adequate reserves, require an installed capacity of twice the average load, the cheapest type is the motor driven centrifugal pump; the next best the steam turbine driven centrifugal pump; and the most expensive, the triple-expansion pumping engine.

Assuming a plant having a machinery capacity of 400 m.g.d. and

an average delivery of 200 m.g.d. against 150 feet of head, the investments and total annual charges of the three types were estimated as follows:

TYPE	INVESTMENT, DOLLARS	PERCENT OF LARGEST	TOTAL ANNUAL CHARGES, DOLLARS	PERCENT OF LARGEST
Triple expansion engines	4,680,000	100	726,150	100
Steam turbine driven centrifugals	2,800,000	59.8	670,920	92.2
Motor driven centrifugals	880,000	18.8	635,230	87.5

Considering the element of *reliability*, Mr. Fenkell's report stated that, if motors are supplied with electric energy from a central power station over transmission lines, there are bound to be interruptions in the supply of current due to storm or other causes. This is a condition not to be permitted in a direct pressure system. If the electrical energy is generated at the site, the element of unreliability is largely eliminated, but current produced in a comparatively small power plant would cost more than in the large power station of the Public Lighting Commission, and the apparent financial advantage of motor driven centrifugal pumps would probably disappear. In low service, however, the element of reliability is not so important as the pumps operate behind reservoirs containing excess capacity for such an emergency and a failure of electric energy up to one hour can be tolerated. The recommendation was that for high service pumping, steam turbine driven centrifugal pumps and for low service pumping, motor driven centrifugal pumps be adopted for estimating purposes; but that the final decision should be based on detailed plans and bids from machinery manufacturers.

Finally, the report of the Consulting Engineering Board of January 5, 1924, made the following recommendation regarding pumping equipment:

"The pumping machinery at the *new* stations should be centrifugal in type, and the pumps for both high and low service should be steam turbine driven"

EARLY SPRINGWELLS STUDIES

The new Division of Engineering, organized in 1925, proceeded with its early studies in accordance with the recommendations of the Board of Consulting Engineers. Various general layouts and estimates were made, including the High Lift and Low Lift Pumping

Plants and the Power Plant, all based on the use of steam turbine centrifugal pumps.

One of the early and difficult problems was the determination of a proper design for the Low Lift Pumping Plant. The raw water was to reach this plant through a 12 foot tunnel having its invert over 80 feet below the ground surface at the site.

The requirements as to depth together with the soil conditions made it desirable to keep the size of the station to a minimum, and led naturally to a circular structure as being best adapted to resist the probable pressures exerted by the earth.

Another important element in the design was water surge. This station was to operate at the lower end of approximately 12 miles of a large tunnel and provision must be made, in case of sudden shutdown, to absorb the kinetic energy of about 210,000 tons of water moving with a maximum ultimate velocity of 6½ feet per second.

The first plant layouts were circular structures, containing eight steam turbine driven centrifugal pumps and incorporating a 25 feet diameter surge tank from which the pumps took their suction. This arrangement called for an outside diameter of 140 feet, a depth of substructure below finished grade of 100 feet and the pumps and steam turbines set 65 feet below grade and about 30 feet below Detroit River level and a total cost of over $2,000,000. These first layouts were, therefore, not satisfactory. The construction problems were unprecedented, the absolute operating reliability open to some question and the cost excessive. The relatively large size for the plant was the result of the use of horizontal centrifugal pumps driven by steam turbines, through reduction gears and the incorporation of a surge tank within the structure.

This situation led to two distinct studies involving the relative costs of steam turbine, as against electric motor driven centrifugal pumps, and in addition for the Low Lift Pumping Plant the consideration of a water turbine driven centrifugal pumps, and an investigation into all of the elements affecting design, construction and operation of the plant. These studies, by the engineering staff of the department, finally determined the design and construction of the plant

RELATIVE COSTS

The first of the above mentioned studies was made by the engineering staff of the department in coöperation with the engineering department of the Detroit Edison Company.

The following types of drives for centrifugal pumps were considered:

1. Steam turbines with reduction gears;
2. Electric motors,
   (a) Combination of constant and variable speed type,
   (b) Slip ring motor type (variable speed);
3. Steam turbine drive in the high lift plant and water turbine driven type in the low lift plant;
4. Steam turbine drive in the high lift plant and direct current drive in the low lift plant.

The first studies of the Detroit Edison Company Engineering Department, submitted in October, 1926, stated:

"(1) The total investment required for each type of motor drive is less than for turbine drive.

"(2) The annual costs for fuel, maintenance and payroll is less for motor drive than for steam turbine drive.

"(3) The reliability afforded by motor drive is at least equal to that of turbine drive." This conclusion was based on the installation on the site of turbo-generators having a capacity equal to the "Maximum hour and a standby transformer installation equal to the difference between total connected load and maximum hour," and also equal to the capacity of one turbo-generator, to shutting down for overhaul.

"(4) Capacity and head regulation adequate for conditions of minimum, average and maximum demand can be obtained by providing one or two variable speed slip ring motors in each service."

The final preliminary studies of the Water Department Engineers, submitted in September, 1927, presented comparative estimates of a steam turbine driven and an electric motor driven plant and showed the steam turbines to be slightly more than the motors in construction costs and also somewhat more in operating charges; and concluded that it was not believed that there is enough difference in the first cost or in operating cost of either of the two types of plants to make either one better than the other.

COMPARATIVE COST ESTIMATES

The estimates showed the comparative costs in table 1. These are not complete costs but only for that part not common in all four plans; they are comparative costs only.

TABLE 1

Comparative costs

	CONSTRUCTION COST, DOLLARS	PER CENT OF HIGHEST	ANNUAL OPERATING COSTS, DOLLARS	PER CENT OF HIGHEST
1. Steam turbines throughout........	2,319,050.00	90.58	619,630.00	93.58
2. Electric motors throughout........	2,316,560.00	90.49	588,160.00	88.83
3. Steam turbines in high lift and water turbines in low lift........	2,559,360.00	100.00	662,110.00	100.00
4. Steam turbines in high lift and D. C. motors in low lift........	2,537,050.00	99.12	638,470.00	96.43

LOW LIFT PLANT STUDIES

These studies were carried out under the direction of the four Assistant Engineers of the Division of Engineering of the Department of Water Supply and a Consulting Engineer. The results accomplished up to April, 1928, were presented in a report which contained sketches and cost estimates covering 21 different schemes, all involving centrifugal pumps as follows: 9 designs with vertical motor driven pumps in a circular plant; 4 designs with horizontal motor driven and 3 designs with horizontal turbine driven pumps in a circular plant; 3 designs of rectangular plants with both horizontal motor and turbine drive; and two special designs of cellular structures, built up of independent shafts, each shaft containing a vertical motor driven unit. This report reviewed the problems involved in the several designs from the standpoints of construction difficulties; water surge adequacy, which subject was later investigated experimentally by the engineering staff of the department; operating reliability; and the cost.

A portion of this report deals with the relative reliability of the *two* practicable kinds of motive power, namely, steam and electricity. On account of cost, water turbine driven pumps were eliminated.

The principal comments on the use of steam were that, as the steam turbines must be placed about 70 feet below finished grade, long vertical high pressure feeder mains would be required; that the support of these mains introduced unusual structural problems; that a break of a steam feeder in a plant so far below ground might result in serious injury or death to employees. As to high speed turbines, an accident resulting in a broken turbine casing was thought a

possibility, and such an experience was cited. Finally, the steam turbine installation would be subject to the possibility of flooding from water in the event of a broken pump casing; and an experience of this nature was mentioned.

Discussing the reliability of electric motors the report stated that: "Assuming motors placed out of the reach of flooding, the chances for interruption of service are limited to the failure of the motors themselves or the failure of the source of supply."

The contingency of flooded motors was eliminated by the use of vertical units, with the motor floor placed above the level of the Detroit River. In the plant, flooding of any sort has been reduced to the possibility of a broken pump casing, as the surge chambers and discharge fumes are incorporated in the outside walls of the structure.

MOTOR DRIVE ADOPTED THROUGHOUT

On the basis, therefore, of a lesser cost in the plant as a whole, and of greater reliability in the Low Lift Pumping Plant, electric motor equipment throughout, with an adjoining steam generating plant, was adopted for the Springwells Station; the drive adopted was alternating current motors with combination of constant and variable speed motors.

Formal approval of the motor driven centrifugal pump type was given by the Board of Water Commissioners on July 11, 1928.

THE PUMPING PLANT

The pumping plant structure, as constructed, houses the low and high lift pumps in one single building; the building is 386 feet long, 100 feet wide, and 40 feet high above grade. The low lift pump pit is approximately 58 feet inside diameter and about 110 feet deep; the outside diameter is about 90 feet. The high lift pumps are placed in pits, two pumps per pit, each pit being about 60 by 30 feet and 20 feet deep.

THE POWER PLANT

Although a complete discussion of the several problems considered in connection with the steam and electrical equipment is beyond the scope of this paper, still a brief summary of the adopted equipment and design basis seems desirable.

The steam operated turbo-generator plant, which will have an

ultimate capacity of 27,000 kilowatts in four 5000 KW main units and four 500 KW auxiliary units, has now installed 16,500 KW in two main and three auxiliary units. One 5000 KW transformer is also in place. Steam for the operation of the turbines is furnished from two 1000 HP water tube boilers; the ultimate installation calls for two additional similar boilers. Each boiler will have a maximum capacity of 90,000 pounds of steam per hour at 360 pounds per square inch gauge pressure, with total temperature of 715 degrees, Fahrenheit. Each boiler is equipped with superheater, economizer and air preheater and underfeed stoker. The fuel to be used is coal burned on underfeed stokers, operated on forced and induced draft.

The electrical switching equipment for the motors of the pumps and generators is housed in a building between the pumping plant and turbine house. Engineering studies were made as to the relative advantages of 4600 volt alternating current as against 2300 volts and because of greater economy 4600 volts was adopted. Similarly after a study, a 440 volt system was adopted in preference to 220 volts for the auxiliary motors. The switch gear used is metal clad type for the 4600 volt system and steel cubicle type for the 440 volt system. All the oil circuit breakers are operated by D. C. Solenoids, push-button, remote control type. Direct current at 250 volts is used to drive the Power Plant auxiliaries and this power is generated in three 400 KW motor generator sets, operating on the 440 volt alternating current system. The excitation power for the synchronous pump motors is secured from three 50 KW motor generator sets, having 440 volt alternating current motors and 220 volt direct current generators. The synchronous motors, driving the main pumps, are started through reactors, which require the use of two oil circuit breakers. This design was found to be the most economical of the several plans considered. The slip ring motors driving the main pumps are designed for a speed variation of from 80 to 100 percent, in four steps, which permits a pump capacity variation of 50 percent. The speed of the variable speed pumps is controlled from the switchboard.

PLANT COST

The additional supply project of Detroit represents an investment of approximately $23,000,000.00, of which about $7,000,000.00 is for the pumping and power plants. The pumping plant structures and equipment cost $3,500,000.00.

ADAPTING CENTRIFUGAL PUMPS TO THE REQUIREMENTS

It is beyond the scope of this paper to discuss the many and complicated problems arising in connection with selecting sizes of centrifugal pumps and the characteristics of them, but brief mention should be made of some of these problems.

In a direct pressure water system, with variation of load of 1 to 4 between minimum and maximum hour pumpage, the size of units to use is one of most importance. In the Springwells Station, the size and number of pumps were chosen so as to give a wide range of flexibility and so as to operate the majority of the pumps at or near rated pump capacity condition.

The next problem of importance was the head-capacity characteristic of the centrifugal pumps to meet the anticipated load requirements. This results in complications in that as the capacity of the load increases, the pressure goes up also, whereas the capacity of a centrifugal is the reverse of this condition; for these reasons pumps with steep head-capacity characteristics were required.

After a study of the above conditions, specifications were drawn up so that pumps would be required to meet the imposed load curves, as anticipated. Pumps were purchased on contract with competitive bidding and the contract awarded to the "lowest responsible bidder." The lowest bidder was determined on "evaluated bid" basis; there was a predetermined value set up for the "weighted overall efficiency" of each pump. The pumps are subject to a field test to determine the bonus or penalty to be applied on the contract. The field tests have not yet been made.

(Presented before the Central States Section meeting, September 22, 1933.)

QUICK CLOSING VALVES FOR ISOLATING BREAKS IN LARGE MAINS

By William W. Brush

(Chief Engineer of Water Supply, Department of Water Supply, Gas and Electricity, New York, N. Y.)

We usually designate as large water mains those that are from 20 to 48 inches in diameter, the 48-inch diameter main being generally the largest size cast iron pipe installed in a distribution system. As the use of cast iron pipe for distribution purposes is almost universal, both in the United States and Canada, the breaks that occur are virtually limited to pipes of this material.

A break in cast iron pipe is generally caused by the metal being stressed to the point where a crack will be started, and due to the lack of elasticity of the metal, the excessive stressing of the metal continues at the end of the crack, causing the crack to extend until finally it is of sufficient length to permit the pressure of the water to tear out a section of the pipe. The portion of the pipe wall that is the last to give away is generally found to show a fracture that makes an angle of 45 degrees to the adjoining pipe surface, instead of 90 degrees, as is the case for the major portion of the crack, the metal being actually torn asunder by the pressure of the water. The opening in the pipe resulting from the break is often equal to the cross sectional area of the pipe itself, and therefore the water escapes at a very rapid rate.

The writer has known of a break in a 48-inch main in New York City permitting a flow to take place at the rate of about 150 million gallons a day, whereas the usual flow through a 48-inch main is at the rate of approximately 20 million gallons a day. Such an enormous volume of water coming to the surface of a city street quickly fills the sewers, floods cellars, breaks up pavement, stops traffic, and where there are rapid transit subways, may flood such a subway to a depth that prevents the operation of trains. Pressures in the distribution system may be lowered to such an extent that there may be no water on higher ground, and an insufficient pressure for domestic

use and fire protection over a very large area will result. This condition continues until the flow is stopped, and the desirability of promptly stopping such flow is obvious.

VALVES USED TO CONTROL FLOW

The flow through water mains is almost universally controlled by the disc type of valve, which is raised or lowered by the operation of a screw stem, gears being generally used on valves more than 20 inches in diameter. With an unbalanced pressure of say 40 or more pounds per square inch on one side of a valve disc, the resistance to the closing of the valve is enormous. It is not an uncommon experience to require four to six men to close a 36- or a 48-inch valve, the men using a six-foot, or even longer bar, to obtain the necessary leverage to close the valve. If the valve is of the usual type it will require a half an hour or more to close it by hand. As each break in a water main involves the closing of at least two head valves, and usually several valves on side connections, it is obvious that with the ordinary type of valve there cannot be a very quick shutting off of the flow of water.

TIME REQUIRED TO SHUT OFF THE FLOW FROM A BROKEN WATER MAIN

When a break occurs in a water main the water department officials usually receive word of it either through a police officer or a citizen who sees the escaping water, telephoning to the water department office. At least five to ten minutes are likely to elapse between the time that the water commenced to flow from the main before the water department has knowledge of the break in one of its mains and the location of such break. If men are held at all times to respond in case of a break or other emergency occurring in a water supply system, and this is the case in New York City, the transportation of gangs to the scene of the break will be dependent upon the traffic conditions and the distance to be travelled. Twenty minutes is believed to be a fair average time for the transportation of the gang, although this time may be readily exceeded, and in some instances materially shortened. If there is only one gang, and that gang must shut all the valves, the two head gates must be first closed, and then the side gates, so that on a 36- or 48-inch main break it is seldom that a shut down is effected in less than an hour, and the time required is usually from one to two hours.

WHAT IS DONE TO REDUCE THE TIME TO EFFECT THE SHUT DOWN

Water works superintendents have for many years struggled with this problem of endeavoring to provide means for quickly shutting off the flow from a broken water main, and at the same time avoiding what would be generally considered an excessive cost for being ready to perform such work and actually performing it when required. The number of breaks in the distribution system is very small compared with the number of miles of mains, and in many cities there may not be a single break in the course of a year. Some of our larger cities, including New York, have utilized a device for mechanically closing valves, that is mounted on an automobile truck, and through suitable gearing is driven by the truck motor. After such device is centered over the operating nut of a valve, a 48-inch valve can usually be closed in approximately ten minutes, but several minutes may be required to center the device. In New York City eight of these trucks are in use. It has been found that their use has not substantially lessened the time required to make shut downs. Valves equipped with electrically driven motors are occasionally installed, and if regularly tested and inspected, give satisfactory results, but they are both expensive to install and maintain. Valves equipped with cylinders and pistons, to be operated by hydraulic pressure, also represent a higher first cost, but require comparatively little maintenance. A serious drawback to these valves is that when a break occurs the pressure is so lowered that there may not be sufficient residual pressure left to operate the valves, and it may be necessary to operate them by a hand pump, which is a slow process. There have been various valves designed that are automatically operated if a drop in pressure occurs, but here a serious difficulty is presented, as the automatic closing of one valve may so increase the flow through another valve that it in turn will close, and this process continue to the point where the shutting off of the water due to the automatic closing of valves is even more serious than the condition caused by the original break.

In the city of New York the Catskill tunnel extends for some seventeen miles under the city. At intervals of slightly less than a mile there are pipe connections leading from the tunnel, in the rock, to chambers just below the surface of the street where the water is delivered into the distribution system. Deep down in the rock, valves have been installed, on these connections, which, through the application of the Venturi meter principle, may be automatically closed if

the flow through the valve is in excess of any predetermined rate. However, this automatic feature is not utilized, because if it were put into use a break on a large main in one part of the city would cause the valves on the connections from the Catskill tunnel in the immediate vicinity of the break to close. Automatically the closing off of the nearest connection would throw the load on the next connection to the north and to the south. These connections would also close, and possibly even further away connections might close, thus depriving a large area of the city of its water supply.

While the development of means of automatically closing valves, or closing valves by mechanical devices, may be perfected in the future so that such devices will be practical from the viewpoint of the water works superintendent, for the present it seems as if hand operation of the majority of valves in the distribution system is now necessary, and probably will continue to be necessary for some time to come. It would therefore appear that a type of valve that can be readily operated by hand, and quickly closed, is very desirable. One must keep in mind, however, that a large valve should not be closed too quickly, due to the water hammer that is developed if a rapidly flowing stream is stopped in a very short time. It is probable that a 36- to a 48-inch valve should not be closed in less than five minutes, from the viewpoint of safeguarding against excessive water hammer.

The writer has made some inquiry as to the results obtained from the use of the so-called Butterfly valve, which is essentially a disc held on a shaft, and when revolved closes and opens the pipe, on the same principle that a damper is operated in a stove pipe. The general experience in the past with butterfly valves used on distribution systems has not been satisfactory, and comparatively few of these valves have been used The writer believes that the major portion of the difficulties experienced have been caused by an attempt to make these valves function as tight shut off valves, instead of functioning, as he believes they should function, as valves to stop excessive rates of flow, utilizing the usual form of sliding disc valves to make tight shut offs. Butterfly valves have, however, been recently designed that it is claimed make a tight shut down, and at the same time are of sufficiently simple and rugged construction to be available for water distribution systems.

In the city of New York, where the municipal system consists of some 4500 miles of water mains, there have been in the past approxi-

mately 300 breaks each year, although this number has in very recent years been reducing, and has now reached approximately 200 breaks per year. It is believed that for New York City conditions the installation of a quick closing valve, such as a Butterfly valve, is justified, even if such a valve is utilized only to control flows where breaks occur, and is installed as a supplement to the existing sliding disc valves. Each water works superintendent must, however, decide whether quick closing valves are or are not needed, and if so, where such valves are needed. The writer, however, ventures the guess that there are few if any of the larger distribution systems throughout the country where one or more quick closing valves would not be desirable, and in most instances, essential, for satisfactory operation of the system.

(Presented before the Chicago Convention, June 15, 1933.)

CHARGES FOR DOMESTIC WATER SUPPLY IN CANADA[1]

PETERBORO

By R. L. Dobbin

(General Manager, Public Utilities Commission, Peterboro, Ontario, Canada)

When waterworks plants were first established, charges for the service were made on some flat rate basis, and in many communities this system has continued to the present time.

However, there were some services metered, mainly industrial and commercial, the reason for this being probably because of the wide variation in the use of water for these purposes.

Gradually, however, for one reason or another, the installation of water meters on domestic services became increasingly prevalent, until at the present time there are many communities with meters on all services.

In Canada, in 1888, there were 68 waterworks plants with a total of 172,947 services and 2,077 meters, that is, 8.3 percent of the services were metered. These figures were compiled from the Manual of the American Water Works published in 1888 by Engineering News of New York. No plants were fully metered.

The latest figures available from the Canadian Engineer's summary of waterworks statistics shows that there are now 599 plants with a total of 1,483,670 services and 294,548 meters. Thus 19.9 percent of the services in the dominion are metered.

There are now 69 plants, large and small in the dominion, with meters on all services, and the number of meters in these plants is 202,081, serving a population of 1,100,000 and with an average daily consumption per capita of 80 gallons.

The remaining 530 plants have 92,567 meters on 7.2 percent of the services. Practically all of them report industrial services fully metered and the average daily consumption per capita is 100 gallons.

[1] Presented before the Canadian Section meeting, March 23, 1933.

Apparently from the above figures, while the number of fully metered plants has increased, these are yet very much in the minority. The consumption per capita is smaller in the fully metered plants, but whether the total reduction is due to installation of meters on all domestic services cannot be definitely stated because of the variations in amount supplied to industrial consumers. In some cities 30 percent of the pumpage is supplied through comparatively few meters to industrial consumers.

BASES OF RATES

Flat rates are usually based on the size of the premises supplied; the frontage; the assessed value; the number and kind of fixtures, or some such standard. They vary materially in various cities, and in most cases are survivals from the earliest beginnings of the plant.

Meter rates consist of either a service charge, or meter rental, plus a consumption charge; or a minimum charge for a fixed quantity of water plus a consumption charge for all used in excess of the minimum.

Flat rates

They are simple and capable of being easily understood by the consumers, and do not vary from month to month, except for occasional changes as to the items on which they are based.

Billing is very much simplified, and the rates may be collected in advance, eliminating the need of deposits. They assure a stability of income which is very important in times like the present. There are less opportunities of argument with the consumers over high bills, etc., and consequently better public relations.

There is no reason for the consumer to economize on lawn watering with resulting loss in the appearance of the city.

It is difficult to make an equitable distribution of charges amongst the consumers unless the flat rates are very carefully designed. There is no check on wastage, except in so far as this is taken care of by periodic inspection, and the efficiency of this inspection depends on its frequency and the personal reliability of the inspector.

Meter rates

When properly designed meter rates result in distributing equitably the charges according to the use of water in the premises, and do check wastage. All consumers have equal privileges at the same cost. No

irritating inspections are required and wastage of water is automatically charged to the waster.

Meters entail, however, considerable capital investment in the meters and setting. They complicate the billing and increase materially the number of trouble calls on the department.

They necessitate increased maintenance costs for repairs and testing and require the employment of meter readers.

They are always collected after the water has been consumed, and, therefore, the guarantee of the landlord or a deposit is required to insure collection of revenue. The revenue collected by meter rates is not stable and varies according to business conditions. At the present time many fully metered systems are experiencing a serious drop in revenue due to economy in the use of water.

If, in an effort to provide a considerable stability in revenue, the minimum charge is set too high, then the advantage of meters is destroyed.

Whether flat or meter rates should be adopted depends on various factors. If water is scarce, or requires expensive treatment or pumping, then there probably is considerable saving in metering, but if these conditions are not present then it may be that flat rates are the most economical in the long run.

Fully metering domestic services will not be profitable unless the savings through metering will not only pay the additional costs thus necessitated, but will also prevent or postpone further investment in equipment or increased capacity.

WINDSOR

By G. C. Storey

(*Secretary-Manager, Water Commission, Windsor, Ontario, Canada*)

On looking over some of our old correspondence, I find a letter dated 1920 stating that the Water Commissioners of the City of Windsor were practically committed to a metered system. At that time there were only about 50 meters in service, largely in the principal factories and hotels. The water consumption per capita was then on the decline having dropped from about 275 during 1914 to 1918, to about 225 gallons per capita in 1920. Nothing much was done, however, until the years 1925, 1926 and 1927, during each of which about 1000 meters were installed. At this time plans were

under way for the construction of a filter plant, water having formerly been pumped directly from the Detroit River. It became necessary to eliminate any abnormal pumpage as this would increase rates by making it necessary to build a filter plant which was larger than should normally be required for the community. The properties first metered were business properties, apartments and those residences where the wastage seemed to be the most persistent. This included, of course, many old houses with hopper toilets which have always been proverbial wasters. If these are carefully operated, however, there is no reason why their water consumption should be abnormal. Nevertheless it is generally very high and it is difficult to get the co-operation of the water users in preventing this wastage.

From 1920 to 1925 the pumpage per capita had dropped from 225 to 175 gallons, while from 1925 to 1927 it dropped from 175 to 120 gallons per capita. Due to the fact that a pitometer survey for leaks was conducted simultaneously with the installation of these 3000 meters, it is somewhat difficult to allocate the division of responsibility for this reduction. Beginning in 1928, 3000 meters were installed yearly (practically all on domestic services) until the completion of the metering program, when something over 13,000 meters were operating. During that time the pumpage per capita had dropped from 120 in 1927 to 82 gallons per capita in 1932. Again we find ourselves at a loss to definitely apportion the reasons. The situation this time is complicated by the fact that we reduced our pressure on the system, principally at night. Formerly at the centre of our distribution we carried 75 pounds at night, whereas now we are carrying only 40. The day pressure is, however, maintained at 40 pounds and is actually somewhat higher than carried in 1928 when the pressure on period of heavy pumping would go under that point. There is another item affecting this reduction, due to the fact that during 1932 and the latter part of 1931 we carried out a pitometer survey covering about 80 percent of the City. The balance will be completed early this year. We have the three factors therefore entering into the last decline of water pumpage; the meter installation on domestic services, the reduction of pressure on the system and the pitot tube survey.

BASIS OF RATES

Water rates in Windsor from 1889 until 1928 have been collected on the basis of assessed value, excepting those few properties which

were metered. This system led to certain inequalities due to the fact that the service rendered to each property was not in proportion to its value. The rate was not in direct proportion to the value of the assessment, but increased as the assessment increased. In 1929 a rate structure was adopted which is still in use, rates from year to year having been adjusted so that the revenue is commensurate with the expenditures. The first item in the schedule of annual rates consists of one mill on the assessed value for fire protection. Some years ago the City council and the Board of Water Commissioners were unable to reach an agreement on the amount to be paid by the city for hydrant rental. The compromise was reached by the Board of Water Commissioners assuming the entire collection of this rate with the result that it was set in the water rates as one mill on the assessed value. In Windsor, our approximate budget is $280,000 and the one mill figured on the assessed value of $80,000,000 brings in $80,000 which with the 10 percent discount allowed, results in about $70 net on each of 1000 hydrants.

The cost of laying the water mains in Windsor is covered by debentures, the charges of which are included in the water rates. This is met by charging a frontage rate on all mains for a period of 20 years from the date of their installation. The rate is 6 cents per front foot on improved property and 8 cents per front foot on vacant property; with an allowance of 120 feet for flankage on corner lots. This results in a revenue of about $30,000 yearly, which, with the hydrant rate of $70,000, pays for the whole cost of water mains and all the costs incidental to fire protection, such as debentures and maintenance costs of hydrants, extra pumping plant other than would be required for domestic service, etc.

The two other items on the bill are the annual service charge based on the size of the meter, and the water rate of 6 cents per 100 cubic feet of water used. These two items taken together cover the various other costs. The annual expenditures are allocated in such a way that those expenses which are a constant quantity on the property and do not vary with the amount of water used, are met by the service charge. Other expenses which are in proportion to the amount of water are met by the water rate of 6 cents per 100 cubic feet. This has always seemed to us an eminently fair method of arriving at charges. For example, the cost of filtering water is collected in the water rate, because the extra quantity of water used on the premises directly affects the cost of filtration. The cost of reading meters,

on the other hand, is an item which is not affected by the amount of water used, and this is borne in the service charge.

Certain items are very difficult to classify. For instance, in Windsor we bear the expense of maintaining the water service pipe in good condition from the water main to the stop box at the property line. It might be argued, and we ourselves were under the impression for a few years, that this was a cost which should be met through service charge collections, as we felt that the cost of repairing this service was not a function of the water used. A service pipe carrying 1000 cubic feet of water yearly might just as easily develop a leak as one carrying 10,000 and, therefore, the cost of this work should be divided equally among the various services, being larger for a larger service than for a smaller one. The cost of searching for these leaks is also an important item and comes under the same classification. We have changed our minds recently, however, on this subject on the ground that, in keeping these leaks repaired, a greater saving is obtained by the larger customers using the greater quantity of water. If a system were allowed to deteriorate so that the pumpage were to become double the normal pumpage, and the actual sale of water were to remain the same, then the large user would find his bill increased by several hundred dollars yearly. By keeping the underground distribution system in good order, a very great saving therefore results to the large users and for this reason they should pay more than their pro rata share of the cost of doing this work.

COSTS

Windsor is completely metered and has in active service about 12,750 meters. Of these, approximately 1750 are on commercial and industrial services, with 11,000 for domestic services. We have found that the cost of installation, including all material and direct labor equals $1.83 per meter since 1928, not including any cost for office clerical work, truck expense or foremen's supervision. Assuming the cost of meters at $11.00 and installation costs of $2.50 each, the cost of installing would therefore be $13.50 each. This would work out at about $150,000 for our system. The extra cost due to having a metered domestic system is, therefore,

Interest and principal payments on 20 year debentures issued for the amount of $150,000	$12,000
Share of meter repairing and testing and reading costs	5,000
Total expense	$17,000

Our 1932 expenses for both domestic and commercial meters were as follows:

Repairs and testing	$2,700
Reading	3,800

Our total pumpage now is 82 gallons per capita. If this system were not metered it might be about 132 gallons per capita daily. For a population of 63,000 this would increase our daily pumpage by about 3,000,000 gallons daily, raising our present pumpage of 5,000,000 to 8,000,000 gallons daily. The pumpage of our maximum day in 1932 was 150 percent of our average. The filter plant, therefore, to supply 5,000,000 gallons daily average, would be required to have a capacity of 7,500,000 gallons for the maximum day of the year. If the system did not have domestic meters, the filter plant would require a capacity of 10,500,000 gallons. It might be fair to assume that the increased cost of the filter plant would be $150,000.

Thirty year debentures on a $150,000 filter plant increase would require in fixed charges	$10,000
Additional filter operating expense (chemicals and power)	5,000
Additional power for high pressure pumping	6,000
Thirty year debentures on additional booster mains to the amount of $100,000, would require fixed charges of	6,500
Two additional inspectors for house to house inspection of plumbing fixtures	3,500
Total annual charges without meters	$31,000
Expense of domestic metering	17,000
Net economy	$14,000

WINNIPEG

By T. H. Hooper

(Superintendent of Water Works, Winnipeg, Manitoba, Canada)

Water meters are just as necessary to a water works system as scales are to a grocer.

A consumer pays for the quantity of water registered on his meter. This is an incentive to curb waste through leaky fixtures, etc. A careless consumer soon finds out that it is not profitable to allow leaks to continue.

A consumer who has been billed for excess water hardly ever checks over his fixtures, but immediately puts the blame upon the water meter. This is a condition where the department must step

in and in a courteous manner point out to the consumer the cause of the excess. If there is no sign of leaks the next step is the installation of a check meter or the removal of the meter to the work shop for test.

The check meter system is the installation of a meter which is known to be correct beside the house meter for the purpose of comparison spread over a period of a week. If there is a difference in the reading of the two meters the house meter is removed for adjustment.

The shop test is the removal of the house meter to the shop where the meter is tested by passing through 10 cubic feet of water into a tank which is set on scales, the scales being set so that when the water reaches the set weight, it is shut off and the meter read.

The standardization of meters is, I believe, in the best interest of a water works department. This prevents duplication of purchase of repair parts carried in stock and many other troubles of a multiple nature. A water works department should, when purchasing meters, make the selection not so much on sales talk as from information obtained by actual usage and test. Price should never govern in the purchase, but rather the low maintenance cost over a term of years.

Meters should be removed at regular intervals for cleaning and adjustment if required, the period to be determined by the nature of water supplied. A water meter is more or less rugged in its manufacture, but it has a great strain placed upon it if foreign matter such as algae is allowed to become deposited in it.

RATES IN USE

In Winnipeg water rates are collected quarterly in advance, a discount of 5 percent being allowed if rates are paid on or before the 18th day in the first month.

The rates are based on the number of rooms in each house, an allowance of 25 gallons per room per day being allowed. All water consumed over and above this allowance is charged for at 35 cents per thousand gallons.

Take, for example, a six roomed house. The rate is $3.60 with a quarterly allowance of 13,650 gallons per quarter.

The above schedule is "A" and refers to domestic rates only. Schedule "B" covers business rates.

Water sold on meter rate of 35 cents per thousand gallons is subject to special discounts, ranging from 20 to 62 percent calculated on the quantity of water used.

A business that consumes over 800,000 gallons and under 1,000,000 gallons per quarter receives 40 percent discount with 5 percent additional for prompt payment.

In this city the water service is constructed and maintained from the water main to the street line of property free of cost to the owner. The water meter is also installed and maintained by the city without cost to the owner of the property. The above system of charging results in a large credit balance to the water works each year.

HAMILTON

By W. L. McFaul

(*City Engineer and Manager of the Waterworks, Hamilton, Ontario, Canada*)

The flat rate in our city is based on the assessed value of the property, with some additional charges for various extra services.

The rates, in dollars, as last revised, are graded as follows:

Assessed Values	*Semiannual rates*
Under 1,000.00	2.10
25,000.00	20.05
100,000.00 and upwards	47.65

These rates merely indicate the basis on which the charges are made, a very detailed table being attached to the by-law. The rates for metered services are 12 cents per 1000 gallons.

The city of Hamilton's water works was constructed in 1859, and from the records, the consumption per capita in 1871 was 27 gallons. The consumption last year was 117.9 gallons per capita. This is a reduction of 22 gallons over the peak in 1929. This reduction, of course, is reflected in the recorded consumption by meter of the manufacturers and others who are metered.

The unmetered services at the end of 1932 are made up as follows:

House services	39,194
Apartment houses	306
Fire services	138
Total	39,638

Metered services:

Manufacturing	196
Commercial	93

Industrial	112
Ice Machines	214
Schools	72
Railways	15
Miscellaneous	156
Total	858

Approximately 38 percent of the total revenue is received from the metered customers in 1930 and 36 percent of the pumpage was supplied to them.

In 1931, however, 34.6 percent of total revenue was received from metered customers, and 34.8 percent of total water pumped was supplied to them.

The system in Hamilton is almost entirely one of flat rate, based on assessment insofar as the number of customers served is concerned. On the other hand, the metered portion of the system is over one third of the pumpage.

ADVANTAGES

1. Billing may be done twice a year.

2 The rates are based on the assessed value in accordance with the rates established. This gives an automatic increase in revenue with increased assessments, and is convenient from the Council's or Commissioners' standpoint.

3. A considerable saving is made in the operating cost, owing to the absence of cost of installing, maintaining and reading meters.

4. No loss of revenue occurs on the nonmetered services owing to economy or curtailment of use.

DISADVANTAGES

1. Continued inspection is necessary to see that fixtures are kept in good condition and that additional plumbing is reported when added to any premises.

2. Waste of water occurs in extremely cold weather, and in hot weather in the poorer classes of dwellings.

3. Much water is wasted in lawn sprinkling where no meters are installed.

TORONTO

By G. G. Rutledge

Superintendent, Water Distribution Section, Toronto, Canada

In Toronto flat rates are used in charging for water supplied for domestic purposes, excepting in cases where such rates cannot be used with a reasonable degree of equity.

There is a flat rate per annum against each house in which water is available.

For private dwelling houses with five rooms and over, there is a rate per room, a higher rate per room being charged when they are used for boarding and lodging purposes.

In all houses there is also a rate for each outlet for water, the rate being higher for houses other than private dwellings.

Flat rates for water supplied to stables and fountains, etc., for lawn and garden sprinkling, window washing, water power, washing machines, building construction work, etc., trench consolidating and for many other purposes are listed.

Where water is required for other purposes than is covered by the list of flat rates, special rates are fixed after investigation.

The flat rates were established after careful investigation to ascertain the average quantity of water required to be supplied in connection with each, and practically no criticism of them is made by the consumers.

The consumers who feel they are overcharged through flat rates, generally when a small family occupy a house with a large number of outlet fittings from which a comparatively small quantity of water is drawn, should be permitted to purchase a meter approved by the water supply authorities and installed by them, provided a satisfactory location for the meter is available. The maintenance of the meter in a condition satisfactory to the water supply authorities is the responsibility of the consumer.

Only a small percentage of consumers wilfully or carelessly waste water in large quantities, and when persistant wastage is disclosed by inspection, the metering of the services supplying such consumers is the only satisfactory means of stopping the waste or collecting the value of the water supplied.

The metering of a large majority of consumers would not very appreciably reduce the water consumption, and the cost of metering these consumers would be considerably greater than the cost of the extra water supplied under flat rates, where an abundant supply is available and the cost of treatment and distribution is moderate.

CANTILEVER STRESSES IN RING TENSION RESERVOIRS

By Marion L. Crist

(Of Burns and McDonnell, Consulting Engineers, Kansas City, Mo.)

Generally speaking, in smaller circular reservoirs, namely, up to one or two million gallons capacity, ring tension designs are cheaper than other types of first-class construction. This is particularly true of covered structures. Therefore, in the interest of economy, a thorough knowledge of the theory of ring tension design becomes a prime requisite to the designer of reservoirs.

The basic theory is of itself simple. A circular wall of concrete confines the water. Bands of steel, placed horizontally within the wall, hold the concrete together, carrying in tension the stress created by the water pressure against the inner face of concrete. The total tension per foot height of wall at any depth, tending to pull the wall half from half, is:

$$\text{Tension} = 62.5 \times \text{depth} \times \text{diameter of reservoir}$$

This total tension is carried by the wall at any two diametrically opposite points. Therefore, the amount of steel per foot of depth must be sufficient to carry one half of this tension, at the desired unit steel stress. In order to keep a uniform steel stress the amount of steel is increased with depth.

An inherent feature of such a design is the elongation of diameter, as the ring tension steel comes under stress. Just as a toy balloon expands when filled with gas, so, to a lesser degree, do the ring tension bars stretch as the reservoir fills. Since concrete does not stretch as readily as steel, the concrete tends to crack, and, in order to reduce cracking and insure water tightness, ring tension steel stresses are usually reduced below the conventional 16,000 or 18,000 pounds per square inch.

The Hewitt type of ring tension reservoir, now rather extensively used, involves these same principles, but in a slightly different manner. By pre-stressing the steel at the time of construction (before the

reservoir is filled) and throwing the concrete into compression, full steel working stresses can be obtained when the reservoir is subsequently filled, but with greatly reduced elongation of diameter.

While elongation of diameter occurs to some degree in all ring tension designs, it is, on the other hand, equally true that all ring tension walls are more or less restrained at the base where the wall joins the footing. In some designs a joint is made between the wall and footing to provide for relative movement between the two. This joint may be coated with asphaltic paint to reduce friction, and may or may not contain a copper water stop. A design of this nature reduces the restraint at the bottom of the wall to a minimum. However, in fairly deep reservoirs with heavy roofs partially supported on the walls, frictional restraint may amount to 4,000 or 5,000 pounds per circumferential foot.

In many designs the wall is actually dowelled into the footing, creating, at the base, complete restraint to radial movement or making it necessary that the footing move with the wall.

To evaluate the restraint under these conditions is extremely difficult in most cases. Obviously, if the footing happens to be poured directly in rock the restraint will be complete and the base of the wall will not move radially at all, unless failure occurs. But, if, as in most cases, the footing is poured in a trench which is subsequently backfilled with loose material, the restraint will be composed of three factors: First, the ring tension strength of the footing itself, since the footing is in the form of a circle; second, the friction between the footing and the soil beneath; and third, the bearing of the footing against the soil at its outer vertical face.

The first of these three factors depends largely upon the design of the footing ring. If the footing is broken by frequent transverse expansion joints and contains little or no steel, this factor is negligible. If, however, the footing is poured as a monolithic ring without expansion joints, the concrete must fracture in tension before the footing can move radially. In this latter case the maximum possible restraint due to concrete ring tension in the footing, is:

$$R_c = \frac{A \times S_c}{R}$$

where R_c = resistance of footing to radial movement in pounds per circumferential foot due to ring tension in the concrete of the footing,

A = Cross-sectional area of the footing in square inches,
S_c = Tensile strength of footing concrete in pounds per square inch,
R = Radius of the reservoir in feet.

Likewise, the resistance created by any steel in the footing can be computed by arbitrarily assuming an elongation of diameter.

The second factor—friction, of course, is dependent upon the weight on the footing, including superimposed wall and roof weight, and the character of the soil beneath it. Such friction can be evaluated with reasonable accuracy.

The third factor—the bearing of the outer vertical face of the footing against the soil, is dependent upon the character of the soil and the method of construction. If the footing is poured without forms, in a trench excavated in original soil, this factor might approach the bearing strength of the soil, particularly in a large structure where the movement is considerable. If the excavation is made wider than the footing and then the backfill around the outside made with loose material, this third factor may become negligible.

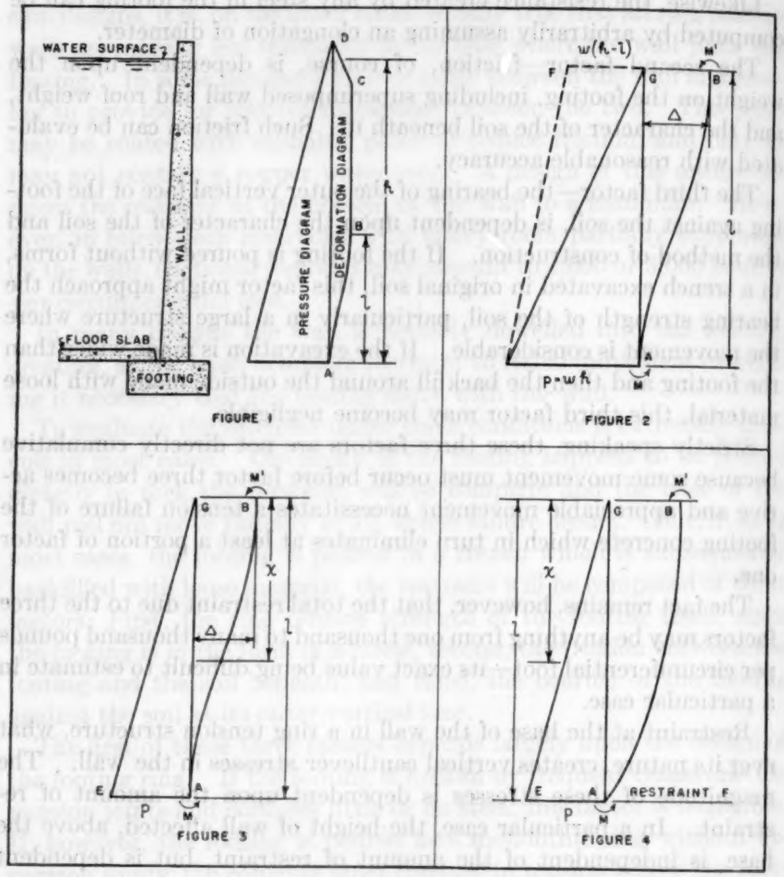
Strictly speaking, these three factors are not directly cumulative because some movement must occur before factor three becomes active and appreciable movement necessitates a tension failure of the footing concrete which in turn eliminates at least a portion of factor one.

The fact remains, however, that the total restraint due to the three factors may be anything from one thousand to many thousand pounds per circumferential foot—its exact value being difficult to estimate in a particular case.

Restraint at the base of the wall in a ring tension structure, what ever its nature, creates vertical cantilever stresses in the wall. The magnitude of these stresses is dependent upon the amount of restraint. In a particular case, the height of wall affected, above the base, is independent of the amount of restraint, but is dependent upon the physical properties of the wall itself. There follows a theoretical analysis of the intensity and location of these stresses.

Figure 1 is a typical section through a ring tension reservoir wall and footing. The line $ABCD$ is an exaggeration of the curve taken by the reservoir wall as the reservoir fills, assuming complete restraint at the base. The elongation of radius will be dependent upon the working stress adopted for the hoop steel. That portion of the curve from C to B is, therefore, a straight vertical line. From D to C

may or may not be a straight line, but there is a gradual increase in hoop steel stress and, therefore, in deflection until the full working stress is reached. The curve at B is vertical and with complete rigidity at the footing is again vertical at A. Between the two points



FIGS. 1 TO 4

the wall assumes some form similar to AB. At A all load is carried by vertical cantilever action, while at B all load is carried by ring tension.

Consider a vertical element, figure 2 at the base of the wall long enough to include AB. Hool and Johnson[1] show that the load caus-

[1] Hool and Johnson, Concrete Engineers Handbook, page 766.

ing cantilever stress on this vertical element varies in approximately a straight line from p at the base to zero at B, the remainder of the loading EFG being carried as ring tension stress. Therefore, AEG represents approximately the pressure diagram for this vertical cantilever element, l being as yet unknown. In addition to this loading the element is acted upon by the moments M and M' which maintain the slopes at the two ends parallel. For a homogeneous beam with this loading

$$EI \frac{d^2y}{dx^2} = M' + \frac{x}{3}\left(\frac{px}{l} \cdot \frac{x}{2}\right)$$

Taking origin at M'

$$EI \frac{dy}{dx} = \int M'dx + \frac{px^3}{6\,l}\,dx$$

$$= M'x + \frac{p}{24\,l}x^4 + C$$

when $x = 0$

$$\frac{dy}{dx} = 0 \therefore C = 0$$

when $x = l$

$$\frac{dy}{dx} = 0 \therefore M' = -\frac{pl^2}{24} \qquad (1)$$

and

$$M = \frac{pl^2}{8} \qquad (2)$$

Point of inflection $= 0.63\ l$ from M' or $0.37\ l$ above bottom

$$EI\,y = \int -\frac{pl^2}{24}\,xdx + \frac{p}{24\,l}\,x^4dx$$

$$= -\frac{pl^2x^2}{48} + \frac{px^5}{120\,l} + K$$

when $y = 0$

$$x = 0 \therefore K = 0$$

$$EI\,y = \frac{p}{120\,l}x^5 - \frac{pl^2x^2}{48}$$

or when $x = l$

$$y_{max} = \Delta = -\frac{pl^4}{80\,EI} \tag{3}$$

For a reinforced concrete beam according to Turneaure and Maurer's formula for deflection[2]

$$\Delta = \frac{1}{40\,E_s} \cdot \frac{pl^4}{2\,bd^3} \cdot \frac{n}{\alpha} \tag{4}$$

where Δ = total deflection in inches,
E_s = modulus of elasticity of steel,
p = pressure in pounds per inch length l at the base of the vertical element,
l = height in inches above the base that cantilever stresses affect the wall,
b = breath of vertical element in inches along circumference of reservoir,
d = depth of element = effective thickness of wall
$\frac{n}{\alpha}$ = numerical coefficient dependent upon p and n

From equation (4) taking b as 12 inches

$$\Delta = \frac{1}{40\,E_s} \cdot \frac{62.5\,hl^4}{144 \times 2 \times 12\,d^3} \cdot \frac{n}{\alpha}$$

$$= \frac{1}{2212\,E_s}\frac{hl^4}{d^3}\frac{n}{\alpha}$$

When the footing is rigidly fixed Δ is also the elongation of radius due to hoop tension, or

$$\Delta = \frac{f_S}{E_s}r$$

where Δ = total elongation of radius due to hoop tension,
f_s = working stress in hoop steel,
E_s = modulus of elasticity of steel,
r = radius of reservoir in inches,

[2] Turneaure and Maurer, Principles of Reinforced Concrete Construction, 2nd edition, page 116.

$$l = 6.86 \sqrt[4]{\frac{f_s\, r\, d^3}{h \frac{n}{\alpha}}}$$

And denoting the total shear at the base of the element by V

$$V = \frac{pl}{2}$$

In the above discussion for a wall of fixed b, d, and $\frac{n}{\alpha}$ the only two factors which vary if the footing moves out a part of the distance Δ are Δ and p. For a rigidly fixed wall p is the full hydrostatic pressure; but if the base of the wall moves out part of the distance, *i.e.*, when restraint is only partial, p becomes just that portion of the hydrostatic pressure which is not taken by hoop stress.

The height of wall, l, affected by cantilever stress, is independent of the degree of restraint. For a given wall, formula 5 contains no quantity which varies with the degree of restraint. If, however, the wall and footing are separated by an expansion joint, or if the footing restraint is such that the footing can tip with the wall, then the situation is very different. Then the base of the wall takes the curve of a simple cantilever—no longer being held perpendicular at the bottom—but with the loading otherwise similar to the first case.

Figure 4, corresponding to figure 3, illustrates the form of the new curve. p again equals total hydrostatic pressure at the base or any portion of it depending upon the degree of restraint. "F" equals total restraint or

$$F = \frac{pl}{2} \qquad p = \frac{2F}{l}$$

By the same reasoning used in the first case:

$$M' = -\frac{p\,x^3}{6l}$$

$$\Delta = 3/40\,\frac{pl^4}{EI} = \frac{3}{20\,E_s} \cdot \frac{pl^4}{2\,bd^3} \cdot \frac{n}{\alpha}$$

$$l = 4.38 \sqrt[4]{\frac{fs\, rd^3}{h \frac{n}{\alpha}}} \qquad (7)$$

$$V = \frac{pl}{2}$$

or in terms of F

$$M' = \frac{Fl}{3} \tag{8}$$

$$V = F \tag{9}$$

Again l, while different from the other case, is independent of the degree of restraint.

A specific example will tend to show that these stresses are of magnitude that requires consideration, and that a tremendous advantage is obtained by separating the footing from the wall.

Assume a ring tension reservoir with a 30 feet water depth. Let the diameter of the reservoir be 100 feet and suppose the wall thickness as determined from ring tension design is 8 inches at the top and 18 inches at the base. Assume a hoop steel working stress of 12,000 pounds per square inch and, in addition to the weight of the wall, assume a roof load of 1000 pounds per peripheral foot carried by the wall.

In the above formulae d denotes the effective thickness of the wall. Where the wall thickness varies, as in this case, it is on the side of safety to use d as somewhat larger than the average d.

Case I. Assume that the wall is to be tied into the footing and that the footing is rigidly fixed in a rock foundation.

From Equation 5, considering an element 12 inches wide

$$l = 6.86 \sqrt[4]{\frac{12{,}000 \times 50 \times 12 \times 15^3}{30 \times 12 \times 100}} = 197 \text{ inches}$$

$$p = \frac{62.5 \times 30}{12} = 156 \text{ pounds}$$

$$M = \frac{156 \times 197^2}{8} = 757{,}000 \text{ inch pounds} \qquad \text{(From Eq. 2).}$$

$$M' = 252{,}000 \text{ inch pounds}$$

$$V = 15{,}400 \text{ pounds}$$

$$\text{Point of inflection} = 0.37\, l = 73 \text{ inches above base.}$$

Obviously M is much too great to be carried by a simply reinforced beam of the effective depth of 16 inches. Yet, an increase in d, even though it need extend up the wall only about three feet, increases the stiffness of the wall, lengthens l, and increases M. Further, heavy diagonal tension reinforcing becomes necessary at the base of the wall. It, therefore, appears that in a reservoir of this size extremely serious cantilever stresses would occur if the wall were tied to the footing and the footing rigidly fixed in position.

This case is not good design to say the least and the continued existence of many such designs can be accounted for only on the assumption that some movement occurs in the footing.

Case II. Assume the above reservoir with an expansion joint between the wall and the footing and that the only restraint is frictional restraint. Assume a coefficient of friction of 0.65.

Then total restraint at the base is

$$\left[\left(\frac{13}{12} \times 31 \times 150\right) + 1000\right] 0.65 = 3920 \text{ pounds per peripheral foot}$$

$$l = 4.38 \sqrt[4]{\frac{12{,}000 \times 50 \times 12 \times 15^3}{30 \times 12 \times 100}} = 126 \text{ inches}$$

$$M' = \frac{3920 \times 126}{3} = 165{,}000 \text{ inch pounds}$$

Effective d where M' occurs = 12.5 inches

To take care of M' assume J as 0.885

$$A_s = \frac{165{,}000}{12.5 \times 0.885 \times 16{,}000} = 0.933 \text{ sq. inches}$$

$p = 0.0062$ Actual $J = 0.884$

$f_s = 16{,}000$ $f_c = 570$

Use $\frac{5}{8}$-inch square bars @ 5-inch centers in outer face of wall.

M' develops rather rapidly near the base of the wall. Therefore these bars should extend vertically upwards from the base, sufficiently beyond the 126-inch point to secure bond. One third of them might well be carried to the top of the wall as tie steel.

Case I illustrates the magnitude these stresses may assume under rather extreme conditions. Case II indicates that they are worth

consideration even though an expansion joint exists between the well and the footing.

Case I should be looked upon as a special case in a general hypothesis. Actually, in almost every case where the wall is doweled into the footing some movement occurs, either radial movement or tipping, both of which have the effect of reducing cantilever stress.

Obviously, the best ring tension design is that which incorporates a joint between the wall and footing, thus reducing restraint to a minimum and making possible a rational solution of the stress created by this minimum restraint.

THE CORROSION OF ZINC IN VARIOUS WATERS[1]

By E. A. Anderson, C. E. Reinhard, and W. D. Hammel

(Metal Section, Research Division, The New Jersey Zinc Company, Palmerton, Pa.)

From time to time in the past the question of the safety of using zinc in contact with drinking water has been raised. We have been interested in the problem in relation to chlorinated water.

In order to investigate the matter, two three-gallon bottles of drinking water from the borough of Franklin, N. J., were delivered at this laboratory. This water is heavily chlorinated. Corrosion tests on galvanized iron were carried out in open and in sealed containers in tests of one and seven days' duration at room temperature. In order to obtain more complete information, similar tests were carried out with pure distilled water, and distilled water to which chlorine was added in amounts of one, three, and five parts per million.

PROCEDURE

Two three-gallon glass carboys filled to the cork with the water to be examined were received about noon of Friday, December 18, 1931. The corks were covered with a heavy coating of wax as soon as the bottles arrived. Storage in a cold location was arranged.

The preparation of samples and containers for the test could not be completed until Tuesday, December 22, 1931, at which time the bottles were unsealed and the tests started.

As the first step in the procedure a sample of the water was submitted for chlorine and chloride determination. The report was as follows:

Chlorine	less than 0.01 part per milli n
Chloride	3.4 parts per million

No odor of chlorine could be detected when the bottles were opened. The absence of free chlorine confirms experience in Palmerton where

[1] From the Research Division of The New Jersey Zinc Company, Palmerton, Pa.

free chlorine gas added at the well head is found only in combined form as chlorides after passing a few hundred feet through the pipes.

Experimental

After some consideration it was finally decided that tests to duplicate conditions in open and in closed containers should be made. For the purpose a number of small glass bottles of approximately 140 cc. capacity were obtained. Loose fitting corks were used to keep out dust from the air in the open test. In the sealed tests the corks were fitted tightly and sealed with paraffin wax.

Published data indicated that the amount of zinc in solution and suspension tended to decrease as the test was continued. To obtain information along these lines, tests of one day and of seven days' duration were run in all cases.

In conducting the tests, weighed specimens were placed in the containers and left at room temperature for the desired period of time. Each test was run in quadruplicate. At the end of the test the specimens were removed and the solutions representing each set of quadruplicate specimens were composited for analysis. This procedure was made necessary by the sample requirements for the analysis.

In the seven-day tests the suspended zinc salts were present in sufficient quantity to make it necessary to filter the solution and determine zinc in solution and zinc in suspension separately.

In addition to the Franklin water, tests were run in pure distilled water and in distilled water to which one, three, and five parts per million of chlorine were added.

Specimens tested

Since the majority of containers in which water might be stored or circulated are made of galvanized iron it was decided to use this material for samples. It was considered advisable to avoid cut edges in order to eliminate any error introduced from this cause. The final specimens were cut into dimensions from black iron sheet and were hand dip galvanized in prime western zinc.

In order to keep the relation between the specimen area and the volume of solution the same as that occurring in closed cylindrical tanks, the specimens were cut to one by two-inch dimensions giving 25.8 square centimeters of surface in 140 cc. of water or 184.5 square centimeters per liter of water. In some of the tests a specimen one-half this size was used. The data in such cases were multiplied by two in the tables.

Analytical accuracy

In order to check the accuracy of the zinc analyses, it was necessary to account for the entire amount of zinc lost from the specimen. This was done in typical instances. In doing this the total amount of zinc contained in dissolved form in the contents of the four check solutions was computed from the analysis (reported in milligrams per liter). The total zinc in suspension was also calculated from the analysis. The adherent corrosion products of the four check specimens were removed in a common solution of ammonium chloride (100 grams of ammonium chloride in 900 cc. of water used at 80°C.) and the total zinc content determined.

The sum of all the above zinc contents should equal the loss in weight of the specimens. A typical example is shown.

TEST	DURATION	ZINC MILLIGRAMS TOTAL				
		In solution	Precipitate	Adhering salts	Total	Loss in weight of specimens
*	7 days	3.3	6.1	40.2	49.6	52.4

* Chlorinated distilled water—5 parts per million of chlorine—sealed test.

The agreement between the total zinc lost and the total zinc recovered is quite good. In running the ammonium chloride test a slight attack occurs on the metal which probably accounts for a large part of the disparity noted. It may safely be assumed that the zinc analyses were substantially accurate. The complete data on this point will be found in table 5.

DISCUSSION OF RESULTS

In considering the data obtained in the present investigation, it is well to include also earlier data obtained in October, 1923.

In the present tests the attempt was made to simulate conditions in storage tanks, both new and closed. In the earlier work a circulating device was used to simulate the passage of water through pipes.

The most significant data are those on the quantities of zinc taken into solution in the water and those held in loose suspension. Zinc in these two forms is available to produce any toxic effects which are possible. These data will be found in tables 2 and 3. For ease in making comparisons, however, a tabulation has been arranged in which much of the older data are included.

WATER	TYPE OF TEST	DURATION, DAYS	ZINC—MILLIGRAMS PER LITER		
			In solution	Suspended	Total
Distilled	Sealed	1	*	*	16
Distilled	Open	1	*	*	4
Distilled	Circulating	1	3.8	3.0	6.8
Distilled	Sealed	7	8	38	46
Distilled	Open	7	4	57	61
Distilled	Circulating	7	40.2	0.6	40.8
Distilled + 1 part per million of chlorine	Sealed	1	*	*	4
	Circulating	1	2.2	3.0	5.2
	Sealed	7	4	18	22
	Circulating	7	1.4	3.0	4.4
Distilled + 5 parts per million of chlorine	Sealed	1	*	*	13
	Sealed	7	6	11	17
Franklin	Sealed	1	*	*	16
Franklin	Sealed	7	12	12	24
Franklin	Open	1	*	*	6
Franklin	Open	7	<2	27	<29–>27
Palmerton	Circulating	1	3.0	3.0	6.0
Palmerton	Circulating	7	11.9	0.5	12.4

* Not determined separately.

Note—All tests marked circulating are the older (1923) tests.

This tabulation deserves critical examination. In the first place it is apparent that only in the case of distilled water and distilled water plus 1 part per million of chlorine does the increase in time from one to seven days greatly increase the amount of zinc in the water. In the case of the chlorinated distilled water the total amount of zinc in solution and suspension is about half of that apparently required to make the water unfit for consumption. In other words, only in waters of the softness and purity of distilled water will the corrosion of zinc be rapid enough to make time an important factor.

The influence of one part per million of chlorine is quite apparent. In all three types of test this addition of chlorine decreased the amount of zinc found in the water. The earlier tests had no chlorine content higher than one part per million. In the present tests three contents were tested. It will be noted that even the highest content (5 parts per million) produced less attack than the pure distilled water.

The chlorinated Franklin drinking water, in spite of a chlorine content of 3.4 parts per million, showed distinctly less zinc in seven

days than the distilled water. The older tests were made on Palmerton drinking water and are in good agreement.

In none of these tests is there any indication that chlorine acts to increase the rate of corrosion of zinc in distilled water. On the contrary all of the tests show that chlorine in amounts up to 5 parts per million will reduce the corrosion rate.

A point of some importance has been brought out in the literature. In numerous tests on the corrosion of galvanized iron or zinc pipes, it has been demonstrated that the corrosion rate diminishes as the time is increased. Thus Rinck (2) finds 30 milligrams of zinc per liter in water held in contact with zinc pipe for four weeks. When this water was removed and a fresh supply added only 3 milligrams per liter were found after two days. These tests were repeated with fresh lots of water and the same specimen. After a number of tests had been made it was found that the corrosion rate had fallen to 2.5 milligrams per liter in five months.

The explanation for this apparent increase in resistance lies in the formation of an adherent film of basic carbonate which is only sparingly soluble in ordinary CO_2 free waters. In the tests conducted under the present experiment, the original high rate of attack was recorded in all instances. There is every reason to believe that no higher values would be obtained in the Franklin water if the water in contact with the specimen were replaced. Only in waters containing CO_2 or H_2S or of very low hardness will the corrosion rate fail to decrease.

QUESTION OF TOXIC EFFECTS FROM ZINC IN WATER

It is difficult to arrive at any definite conclusion from the literature as to the maximum amount of zinc that can be contained in drinking water with safety.

The United States Public Health Service (3) in their standards of June 20, 1925, place the maximum zinc content for culinary and drinking water supplied by common carriers in interstate commerce at the low figure of five milligrams per liter.

J. C. Thresh (4) found about three grains of zinc carbonate per gallon (26.6 mg. of zinc per liter) in a family drinking supply which apparently had caused no ill effects.

Frederick and Forster (5) quote Thresh as stating that in one small community the sole source of water contained 4.9 to 11.2 parts of zinc per million without ill effects.

Hazen (6) reports that at Brisbane, Queensland, in 1907, every house had its own galvanized iron rain water tank in which the zinc content ran as high as one grain per gallon (17.1 milligrams per liter). No harmful results were noted.

Mason (7) gives statistics from cities using galvanized pipe for water supplies. The highest zinc content reported was 18.46 parts per million in West Berlin, Mass. No ill effects were noted.

Schwartz (8) reports on well water which caused vegetables to turn green in cooking and which caused intestinal distress upon drinking. A zinc oxide content of 32.4 parts per million was determined.

Scott and Jameson (9) studied the water supply of a depot of 200 men. No harmful effects were reported, although the zinc content of the water ran as high as 23.8 to 40.76 parts per million. These authors also find that fifteen parts per million of zinc as sulphide will destroy coliform organisms and render water sterile in 48 hours.

Stacks (10) discusses an artesian well supply which caused nausea and fainting spells. A maximum zinc content of 1.8 grains per gallon (30.8 milligrams per liter) was found. A strong odor of H_2S was noted, but no mention is made of the possible ill effects of this gas.

Lehman (11) studied the effects of zinc carbonate on a dog. For the greater part of eleven months the animal was fed 500 milligrams of zinc as carbonate per day. The average dose over the entire period was 460 milligrams per day or 44 milligrams per pound of body weight. This feeding had no ill effect on the health and growth of the dog.

Bartow and Weigle (12) report that waters in the Missouri-Kansas-Oklahoma district contain as high as 50 parts per million of zinc. Rats were fed for several weeks with water containing this amount of the zinc without harmful effects.

Drinker, Thompson and Marsh (13 and 14) fed daily doses of zinc oxide to rats, cats and dogs. The rats received doses as large as 34.4 milligrams of zinc per day for 35 to 53 weeks. The dogs and cats received 175 to 1,000 milligrams per day for 3 to 53 weeks. In no cases was the health of the animal affected. Autopsies failed to disclose any effect on the animals' organs. These workers quote Schlossberger, Michaelis, Sacher, Dragendorff, von Jaksch and Bernatzik as stating that zinc compounds taken into the stomach are converted by the free hydrochloric acid or the free lactic acid to chlorides and lactates. Both compounds are decomposed by the protein substances present to form protein compounds which are dissolved in part by the free acids present.

Apparently the effect of zinc on the human system is governed to a considerable extent by the acid radical with which it is associated. Thus zinc chloride is regarded as the most caustic of the common zinc salts. Zinc sulphate is somewhat caustic, but to a much lesser degree than the chloride. Zinc oxide and zinc carbonate are not considered corrosives.

The products of corrosion of zinc in water naturally will be the oxide, hydroxide and carbonate possibly in some mixed form.

In going over the list of abstracts given above, it will be seen that in no case did approximately 20 milligrams per liter of zinc cause trouble. One case of zinc as high as 26.6 mgm. per liter and one ranging from 23.8 to 40.76 mgm. per liter were noted. In both cases the water was harmless. One case of 32.4 mgm. per liter was reported in which intestinal distress was noted. The case reported by Stacks is a special one and will not be considered here.

There is then only one case where a zinc content of less than 40 milligrams per liter caused distress. In this particular case there is no mention of possible other factors which might have contributed to the illness reported. The writers feel, therefore, that a tentative safe upper limit of 40 milligrams per liter may be set. It should be pointed out that water containing this amount will be milky in appearance and will have a strong astringent taste. If Lehman's observations are correct this characteristic taste will be noticeable before the zinc content has reached dangerous limits.

In the absence of complete information, it is difficult for a layman to arrive at a true estimation of the importance of the zinc content of water. Even at 40 milligrams per liter it is doubtful that much more than 100 milligrams will be ingested daily, since few people will use much more than 2½ liters (3 quarts) of water daily for drinking and in cooked food. Most foodstuffs contain zinc. The following menu (15) of a test meal contains from 225 to 275 milligrams of zinc:

Three-fourth yeast cake with anchovies
Chopped olives and mayonnaise
Twelve oysters (raw)
Oyster soup (eight oysters)
Duck—bread stuffing
Applesauce
Corn on the cob
Wheat bran pudding

Bread and butter
Strawberry gelatin—whipped cream
Coffee and sugar

No ill effects were noted from this meal.

The normal rate of loss of zinc from the human system amounts to about 3 to 20 milligrams per twenty-four hours with an average of about 10 milligrams (15). These amounts represent those taken in in normal food. There is every indication that were larger amounts taken in daily the loss would become correspondingly large and no ill effects would result. In the Drinker, Thompson and Marsh experiments continued feeding of amounts of zinc far beyond what normal diet would involve, produced no ill effect on rats, cats and dogs.

On the basis of all of these considerations, the writers feel safe in considering waters containing up to 40 milligrams per liter safe for human consumption.

SUMMARY AND CONCLUSIONS

The following conclusions are based on the data obtained in the present investigation:

1. Chlorinated drinking water is not abnormally corrosive to zinc.
2. Distilled water is strongly corrosive to zinc in the sense that in seven days sufficient zinc has been taken into solution and suspension to make it unfit for drinking purposes.
3. The addition of from 1 to 5 parts per million of chlorine to distilled water greatly reduces the rate of attack on zinc and eliminates the health hazard.

Analysis of the Franklin water disclosed the presence of 3.4 parts per million of chloride and no free chlorine. This is in agreement with experience in Palmerton where chlorine added at the well head is converted into fixed chloride in a very short time.

ACKNOWLEDGMENT

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TABLE 1

Weight change data on specimens tested—all data in grams

TEST NUMBER	WATER	CHLORINE	TYPE OF TEST	ORIGINAL	FINAL	CHEMICALLY CLEANED	WEIGHT CHANGE	DURATION, DAYS
		p.p.m.						
F-5188	Franklin	None added	Sealed	4.5795	4.5795	*	0.0000	1
F-5206	Franklin	None added	Sealed	4.6254	4.6277	4.6186	−0.0068	7
F-5189	Franklin	None added	Open	9.2794	9.2824	*	+0.0030	1
F-5207	Franklin	None added	Open	9.0179	9.0283	8.9977	−0.0202	7
F-5190	Distilled	None added	Sealed	4.5917	4.5902	*	−0.0015	1
F-5205	Distilled	None added	Sealed	4.6995	4.6983	4.6870	−0.0125	7
F-5191	Distilled	None added	Open	9.2925	9.2948	*	+0.0023	1
F-5204	Distilled	None added	Open	9.2082	9.2077	9.1767	−0.0315	7
F-5199	Distilled	1	Sealed	9.2005	9.2005	*	0.0000	1
F-5212	Distilled	1	Sealed	9.4159	9.4166	9.4035	−0.0124	7
F-5200	Distilled	3	Sealed	9.4261	9.4266	*	+0.0005	1
F-5213	Distilled	3	Sealed	9.4761	9.4762	9.4629	−0.0132	7
F-5201	Distilled	5	Sealed	9.3789	9.3785	*	−0.0004	1
F-5214	Distilled	5	Sealed	9.1801	9.1804	9.1670	−0.0131	7

* Not cleaned chemically—very little adhering material.

Note—All data average of four tests.

TABLE 2

Analysis of solutions—milligrams per liter

TEST NUMBER	WATER	CHLORINE	TYPE OF TEST	DURATION, DAYS	TOTAL WATER	ZINC CONTENT*	ACTUAL ZINC CONTENT
		p.p.m.			*cc.*		*mgm.*
F-5188	Franklin	None added	Sealed	1	545	16†	8.7
F-5206	Franklin	None added	Sealed	7	535	12†	6.4
F-5189	Franklin	None added	Open	1	550	6	3.3
F-5207	Franklin	None added	Open	7	550	<2	<1.1
F-5190	Distilled	None added	Sealed	1	540	16†	8.6
F-5205	Distilled	None added	Sealed	7	545	8†	4.4
F-5191	Distilled	None added	Open	1	555	4	2.2
F-5204	Distilled	None added	Open	7	545	4	2.2
F-5199	Distilled	1	Sealed	1	575	4	2.3
F-5212	Distilled	1	Sealed	7	534	4	2.1
F-5200	Distilled	3	Sealed	1	555	10	5.6
F-5213	Distilled	3	Sealed	7	566	4	2.3
F-5201	Distilled	5	Sealed	1	535	13	7.0
F-5214	Distilled	5	Sealed	7	554	6	3.3

* In solution—see table 3 for zinc in suspension.

† Determined on 1″ by 1″ specimens—all values for these runs are double those actually determined.

Note—All data sum of four tests.

TABLE 3

Zinc in suspension in solutions—milligrams per liter

TEST NUMBER	WATER	CHLORINE	TYPE OF TEST	DURATION, DAYS	ZINC IN SUSPENSION	ACTUAL ZINC	SOLUTION	TOTAL ZINC‡
		p.p.m.				mgm.	cc.	mgm.
F-5188	Franklin	None added	Sealed	1	*	—	—	8.7†
F-5206	Franklin	None added	Sealed	7	12	6.4	535	12.8†
F-5189	Franklin	None added	Open	1	*	—	—	3.3
F-5207	Franklin	None added	Open	7	27	14.8	550	<15.9 >14.8
F-5190	Distilled	None added	Sealed	1	*	—	—	8.6†
F-5205	Distilled	None added	Sealed	7	38	20.7	545	25.1†
F-5191	Distilled	None added	Open	1	*	—	—	2.2
F-5204	Distilled	None added	Open	7	57	31.2	545	33.4
F-5199	Distilled	1	Sealed	1	*	—	—	2.3
F-5212	Distilled	1	Sealed	7	18	9.6	534	11.7
F-5200	Distilled	3	Sealed	1	*	—	—	5.6
F-5213	Distilled	3	Sealed	7	9	5.1	566	7.4
F-5201	Distilled	5	Sealed	1	*	—	—	7.0
F-5214	Distilled	5	Sealed	7	11	6.1	554	9.4

* Not determined separately—solutions clear or opalescent.

† One 1″ by 1″ specimens—these values are double the actual data.

‡ Total zinc in suspension and solution.

Note—All data sum of four tests.

TABLE 4

Zinc in salts adhering to specimens

TEST NUMBER	WATER	CHLORINE	TYPE OF TEST	ZINC,* STRIPPED	STRIPPING SOLUTION	ACTUAL ZINC STRIPPED	DURATION OF TEST, DAYS
		p.p.m.		mgm. per liter	cc.	mgm.	
F-5188	Franklin	None added	Sealed	†	—	—	1
F-5206	Franklin	None added	Sealed	126‡	300	37.8	7
F-5189	Franklin	None added	Open	†	—	—	1
F-5207	Franklin	None added	Open	208	300	62.4	7
F-5190	Distilled	None added	Sealed	†	—	—	1
F-5205	Distilled	None added	Sealed	214	300	64.2	7
F-5191	Distilled	None added	Open	†	—	—	1
F-5204	Distilled	None added	Open	264	300	79.2	7
F-5199	Distilled	1	Sealed	†	—	—	1
F-5212	Distilled	1	Sealed	134	300	40.2	7
F-5200	Distilled	3	Sealed	†	—	—	1
F-5213	Distilled	3	Sealed	140	300	42.0	7
F-5201	Distilled	5	Sealed	†	—	—	1
F-5214	Distilled	5	Sealed	134	300	40.2	7

* Specimens stripped of corrosion products in 10 per cent NH_4Cl at 80°C. Reported zinc in milligrams per liter.

† Not stripped—coating thin.

‡ Specimen ½ size—data given are double actual.

Note—All data are sum of four check tests.

TABLE 5

Balance of zinc lost against zinc recovered—7-day tests only

TEST NUMBER	WATER	CHLORINE	TYPE OF TEST	ZINC IN SOLUTION	ZINC IN SUSPENSION	ZINC ADHERING	TOTAL	LOSS IN WEIGHT OF SPECIMENS
		p.p.m.						
F-5188	Franklin	None added	Sealed	—	—	—	—	—
F-5206	Franklin	None added	Sealed	6.4	6.4	37.8	50.5	54.4
F-5189	Franklin	None added	Open	—	—	—	—	—
F-5207	Franklin	None added	Open	<1.1	14.8	62.4	{<78.3 >77.2	80.8
F-5190	Distilled	None added	Sealed	—	—	—	—	—
F-5205	Distilled	None added	Sealed	4.4	20.7	64.2	89.3	100.0
F-5191	Distilled	None added	Open	—	—	—	—	—
F-5204	Distilled	None added	Open	2.2	31.2	79.2	112.6	126.0
F-5199	Distilled	1	Sealed	—	—	—	—	—
F-5212	Distilled	1	Sealed	2.1	9.6	40.2	51.9	49.6
F-5200	Distilled	3	Sealed	—	—	—	—	—
F-5213	Distilled	3	Sealed	2.3	5.1	42.0	49.4	52.8
F-5201	Distilled	5	Sealed	—	—	—	—	—
F-5214	Distilled	5	Sealed	3.3	6.1	40.2	49.6	52.4

Note—All data in milligrams.

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WHAT COST OBSOLESCENCE?

By Linn H. Enslow

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Obsolescence is costing America millions of dollars annually.

At some period in the serviceable life of any piece of mechanical equipment there comes a time when the cost of operating such equipment exceeds operating costs plus interest and amortization rates chargeable to new equipment installed as a replacement of the existing unit. In the average instance it is not readily apparent when this becomes the case, because frequently the equipment which is still in good order operates smoothly without breakdowns or repair bills of consequence and gives no warning signal that its operating efficiency should be checked up, or that it has in some other way become obsolete.

The definition of the word *obsolete* which is given in the dictionary is that of pertaining to something that has passed out of style or out of use. One synonym for obsolete is the word *antique* and *obsolescence* is defined as the process or the state of becoming obsolete. A piece of equipment or a practice therefore must necessarily become obsolescent before it becomes obsolete. It may or may not become obsolete before it wears out or becomes useless.

In the case of the human machine there is always reached a period of service by the individual when it becomes a problem to determine whether it would be more profitable to retire the man on a pension and substitute a young and more vigorous man, or to retain the older man. In the case of the human machine, judgment and experience of the individual enters with many other factors in determining his value during the inescapable period of obsolescence. In the case of the mechanical machine, however, such factors play no part and by application of purely mechanical tests and analyses one can readily determine the true efficiency and, therefore, the value of making a replacement vs. continued operation and maintenance of existing serviceable equipment.

THE COST OF OBSOLESCENCE IN INDUSTRIAL PLANTS

In the manufacture of goods the producer figures a "factory door cost" of the various items turned out. The competitor which can produce an item with the lowest factory door cost is the one that in good times declares the largest dividends and that in bad times remains in business after others with higher production costs have faded out of the picture. A method of insuring minimum costs of production—one of paramount importance to manufacturers—is the care taken in determining where obsolescent equipment and practice exists in the plant and thereafter the prompt elimination of both. Even though a machine be amortized but ever so little, if it be found after analysis that another on the market is sufficiently more efficient to justify a replacement, no time is lost in making the change and the rapid write-off of the old equipment follows with a net profit.

An example of how such replacements are made without regard to capital expenditure, once the management had been presented with cold figures to show the value to be gotten from such a change, is found in the expenditure of $3,000,000 by the A. O. Smith Corporation to junk 97 serviceable machines at one clip, substituting therefore three new machines capable of greater production than the original 97. To be sure, this represents an extreme case, but it serves to illustrate what is constantly going on to a lesser extent in all successful manufacturing establishments. In the chemical industry replacements are rapid because of destructive effects and therefore the life of equipment generally is relatively short. Even in this field, useful equipment such as pumps, motors, etc., are scrapped whenever more efficient units appear on the market whose performance is guaranteed by the producers. The more competitive the field the more important becomes the place of the plant engineering staff, whose duty it is to lower production costs. There is no let-up in their battle against obsolescence.

It is generally assumed that the plight which the railroads of America find themselves in today has been due to one thing principally—obsolescence. How much of it could have been prevented had railroads been left to keener competition and less governmental regulation is a question which one naturally asks.

Henry Ford has but recently said—"the only permanent thing in this world is change" and C. F. Kettering, that genius, who has been the engineer behind all important developments of the General Motors Corporation, has forcefully contended that "change, varia-

tions, new invention, new styles, new demands—these are the things that make for advancement." It is his belief that "we are only entering the great period of inventive advancement."

WHAT ABOUT WATER WORKS?

Public ownership and lack of competition are as a rule conducive to high cost operations. Contributory to such high costs in municipal practices has been a scarcity of inventive initiative. Failure to recognize, cope with and eliminate the high cost of obsolescence has cost municipalities millions of dollars in the aggregate.

I refer to two or three things principally: One is the little appreciation shown by the powers that be—or for that matter by the public at large—whenever the local manager of the water department perfects a device or makes a major change which saves money for the city. The other matter is the difficulty which the average water works superintendent meets with in procuring funds for making improvements which are apparent to him as being productive of economy, but which the local board of commissioners, the mayor or the council do not sufficiently appreciate. Instead of spending money to save money it too frequently happens that profits from the water department go for park or playground improvements, or for street extensions and the like, whereas if the profits had been returned for plant improvements and replacement of obsolescent equipment, a still greater yield from water works operation would be forthcoming in the years following which could be applied to other municipal enterprise or to reduce water rents and taxes, or both.

McKean Maffit, Superintendent of Water Works at Wilmington, N. C., in a recent stirring address before the North Carolina Section of the American Water Works Association, struck some high notes perhaps when he said that, in failing to secure needed improvements some of the fault could be laid at the door of the manager of the water works when he failed to interest the "powers that be" sufficiently in his problems to procure his fair share of consideration and the requested funds for improvements. He thought perhaps it was just plain cussed laziness on the part of many superintendents when they failed to fight for improvements that they knew were needed and would return a profit to the water department. He felt that too frequently the manager of the department did not take the necessary pains to procure important and essential data covering his plant

operations nor did he prepare the argument in a sufficiently convincing manner preliminary to appearing before the authorities with his request for needed improvements. In consequence, he had not gotten what he went after and as a result the water department suffered from political manhandling which should be avoidable with proper management.

The oratory of Mr. Maffitt was thrilling. It seemed to wake up an inner desire of those present in his audience to do something about it. There was much truth in what he had to say and obsolescence in water works can be eliminated by the water works manager or superintendent who has the ability to determine its existence and what it is costing the town or city and thus fortify himself to sell the idea to the City Manager or others who must in the last analysis be properly apprised of the situation.

Sometimes it is not easy for a local man to convince the average councilman of the soundness of his recommendations when it comes to capital expenditures. In such cases he should find it most helpful to call on a sales engineer representing some manufacturer of high standing to assist him in diagnosing or analyzing a situation and also in the preparation of arguments to be employed. Looking into situations of this sort the sales engineer can frequently make all of the diagnosis needed to arrive at a definite recommendation, backed up by guaranteed performance of the equipment and saving in operating costs. Where there appears to be major items to consider for further economies the no cost investigation and diagnosis of the sales engineer will be accompanied by definite reasons why a consulting engineer should be brought in to report on more extensive improvements with major savings anticipated. The modern sales engineer is a highly valuable individual and his services should not be overlooked by municipalities.

OBSOLESCENCE IN PRACTICE

Illustrations of obsolescence in water works practice and what has been done to overcome it are numerous and varied. Only a few will be cited here.

The savings effected by metering water and discarding the obsolete flat rate practice needs no emphasis. Nevertheless, far too many dollars of tax payers money are annually lost down the sewer in the form of unmetered wasted water—not consumed water.

Chemical feed equipment

The use of solution tanks and solution feed equipment for water coagulation and softening has practically given way to the more economical dry feeders for chemicals. Nevertheless some of the latter have been in use so long that repairs and new parts cost more than is justified. Modernized equipment is lower priced, is easier to maintain in first class condition and has more refined adjustments. It does not require much in the way of a daily saving of chemicals to pay an appreciable profit on expenditures for improved chemical feed equipment. Some of the results in this direction have been surprisingly satisfactory. Automatic control of chemical feed has proven its merit and economy.

Copper services

The modern water department eliminates lead goosenecks, with the need of expensively wiped joints by experienced artisans, and also the use of galvanized pipe for services is rapidly being displaced by the permanent and more cheaply worked flexible copper tubing. Pipe pushers are used to pull through the copper tubing without making a trench across lawn or paving. The up and coming water works superintendent is rapidly replacing obsolete practices with the use of permanent copper services and the consumer is grateful. Copper tubing and fittings should be laid in at the present low prices, for such is one way of getting the jump on obsolescence because in a short time, no doubt, such low prices will themselves have become "obsolete."

Accounting methods

Obsolete methods of store-keeping, bookkeeping, and billing are giving way to the methods perfected in recent times and with profit. Collections are better and losses are reduced.

Chlorinators

In recent years chlorination has produced various economies in water treatment practices and the machines for feeding chlorine have been so perfected that cost of maintenance and operation has been reduced to a minimum. It pays well now to replace the obsolete pressure type machines with the improved vacuum type. The first cost of the latter is practically the last cost and lack of expense for repairs and repair parts is particularly attractive, not to mention

the time and labor spent on maintaining the older type machines plus the seriousness of the inevitable shut downs and greater necessity for duplicate pressure type equipment. The economy of replacing obsolete chlorinators with improved chlorinators has been amply demonstrated at numerous points.

Chlorine

The handling of chlorine has been markedly improved. For the larger works, using upwards of 200 pounds of chlorine per day, the one ton chlorine container has proven a real boon to the operator and has effected an appreciable saving in cost of chlorination. The cost is cut approximately in half, if not more, when one ton containers displace the older type of small cylinders. Less parts for making connections and less labor in making container changes is required.

Flocculation

Mixing and coagulating practices of past years lack just enough to make successful the introduction of the "Flocculator"—a mechanical mixing and floc conditioning device—which bids fair to render obsolete the ordinary baffled mixing chamber. Thousands of dollars in chemical savings has already resulted from use of the "Flocculator" following the ordinary mixing chamber of high velocity. The perfection of this device by M. C. Smith, Engineer of Water Supply at Richmond, Va., was a distinct contribution to water treatment practices and alum saved in 12 months has, by $5000 more than paid the entire cost of the equipment, engineering and installation during its first year of operation. The bill for alum required was reduced by $23,000 for the twelve month period. This development brings to mind the statement of Mr. Kettering previously quoted.

One can not afford to overlook this machine as a device not alone for producing a saving in coagulant bills, but also must consider its use as a means of increasing the capacity of new plants or of going plants when it is installed in existing basins at but slight expense and disturbance of operations.

Pumping

On the whole, the high price of obsolescence is probably found to be most pronounced in the cost of operating pumping equipment. The greatest potential reductions in operating costs can be found, as a rule, to accrue through the improvement of pumping facilities. More dollars, as a rule, go into the purchase of power than into all other operating commodities bought by water departments. Whether the

water be treated or not, the pumping costs are continuous and appreciable. It may be easily proven from case records that obsolescence of pumping equipment has been extremely costly and continues to be all too prevalently so.

The improved design of centrifugal pump units in recent years has made it practicable and a financially sound practice to replace relatively new equipment with that of improved design with resultant remarkable reductions in the cost of pumping. As in the case of the "flocculator" numerous instances can be cited in which the new pump installations have paid for themselves during the first year of operation. In this I would direct your attention to the informative article by H. P. Binder, "The Economic Replacement of Pumping Equipment" (Water Works and Sewerage, December, 1932.)

Inasmuch as this is a Georgia meeting you will be interested in the experience of Waycross, Ga., which spent $12,000 for new pumping equipment and saved roughly $6,000 in operating costs during the first year thereafter. In two years the new equipment will be all paid for and the water department can show appreciable additional profits or it could do the popular thing for the present in reducing the water rate or taxes.

In Water Works and Sewerage for March, 1933, J. Bryan Miller, City Manager of Jacksonville, Texas, in an article on "Overcoming Obsolescence at a Water Pumping Plant" cites Jacksonville's experience with the replacement of a centrifugal pump, which upon careful test had been shown only 49.7 percent efficient, with a new unit that has to date given an efficiency of 79.6 percent. The savings in power costs were $1395.90 the first year which, after deducting the total cost of the new unit installed ($950.62), left a balance of $445.28 on the credit side of the ledger.

At New Brunswick, N. J., on recommendation of Asher Atkinson, City Engineer, the old steam operated station, although still serviceable, was considered sufficiently obsolescent to justify its consignment to standby service and installation of electrically operated centrifugal pumps. Mr. Atkinson informs the writer that operating costs during the first year were reduced from $51,171.24 to $28,479.54, representing a net saving of $22,691.70, or approximately a 45 percent reduction.

The largest displacement of obsolescent equipment in recent years is represented in the new high service Brilliant Pumping Station at Pittsburgh, Pa., which replaces the old steam operated plant. The new station contains six electrically driven centrifugal pumps, with

a total capacity of 160,000,000 gallons per 24 hours which are producing a proven "wire to water" efficiency of over 86 percent for the motors and pumps and 85 percent or higher efficiency for the entire station. The total cost of the new station, as reported to the writer by J. H. Kennon, Managing Engineer of the Pittsburgh Bureau of Water Supply, was $758,000. The first years operating costs for the new station have been $74,700 under the cost of operating the old steam station. This saving has taken place even in the face of the very cheap coal available at Pittsburgh.

What smaller municipalities can accomplish

In referring to the savings effected at the larger stations, one is impressed with the magnitude of the figures, but proportionately the smaller stations show a greater reduction in the cost per million gallons, resulting from replacement of inefficient or obsolete pumping equipment. The high cost of operating obsolete equipment is in the aggregate greater in the smaller municipalities than in the larger, where engineering staffs are available to keep close check on operating efficiencies. This is the case notwithstanding the fact that as a rule the small installations are the more simple to diagnose. The assistance of an engineer can be secured at moderate cost and frequently a survey made by sales engineers representing reliable manufacturers of pumping equipment will prove sufficient for determining potential savings.

The funds of the P. W. A. are available to borrowers of small amounts just as readily as to larger borrowers. Replacement of obsolete equipment can be so positively classified as a "self-liquidating project" that small water departments would do well to make application for the needed capital which not alone results in returning a respectable profit to the town, but will at the same time speed up the wheels of factories and public carriers once more and thereby do double good.

A progressive superintendent, having satisfied himself that money can be saved by replacement of obsolete equipment, should not find it difficult to secure the support of the city authorities in procuring P. W. A. funds for the purpose whenever local funds are not forthcoming at reasonable interest rates. Even though he fails in the attempt, he is no less a wideawake manager, and in the course of time will receive the recognition due him as such.

"What Cost Obsolescence"?—The figures if available would be staggering.

DISCUSSION

Mr. Gibson:[1] I think the Association is due a great debt of gratitude to Mr. Enslow for the preparation of that paper. There is meat for all of us to consider there and a lot of us might have a tough time digesting it if we put it into effect. However, Mr. Enslow did not stress enough of the small things around a plant, the little leaks. For instance, take those of us who have steam driven plants with mechanical lubricators feeding the oil into the cylinders, as compared with the old Detroit type lubricator. Few of us realize what a saving in oil the mechanical feed will accomplish. In the plant at Charleston operating four units, by the elimination of the old Detroit type lubricator and the installation of the mechanical feeding lubricator we have in the last year reduced the cylinder oil consumption almost 50 percent. That means with cylinder oil at 50 cents, which is a fair price for the best grades, in our case a saving of just about $4.00 a day in lubricating oil alone. That is a small saving, but when you multiply that by 365 days in the year it is quite a material sum. There are quite a great many leaks going on in our plants that can be stopped with a small expenditure. The damper method of letting the fireman shut off the steam,—closing the damper by hand and letting the boiler blow off—that fluctuation alone means a material change in the economical use of our engines. All those things amount to a good deal and they could be corrected, but we are just like the fellow who got so close to the foot of the mountain that he could not see the mountain, we are just so close to them that we can not see them and it takes a paper like Mr. Enslow's to point them out to us.

Dr. Slocum:[2] I think we all hear on the radio the two well known colored men whose program always ends up with "See your dentist twice a year," and I should think it would pay the water works of this country if they would do something like that to their plants. Call in a consulting engineer, have him go over your plants and see what you need. This will solve a lot of your engine trouble. Correct the little things before they get so large they will cost you a great deal. You can get a good engineer at a very reasonable cost and he will probably save you much more than he costs you.

(Presented before the Southeastern Section meeting, April 5, 1933.)

[1] Manager, Water Department, Charleston, S. C.
[2] General Reduction Company, Macon, Ga.

WATER SOFTENING AT QUINCY, ILLINOIS

W. R. Gelston, Jr.
(*Chemist in Charge of Softening, Water Works Commission, Quincy, Ill.*)

Before construction of the softening plant, the purification plant at Quincy consisted of two sedimentation basins of 380,000 and 736,000 gallons capacity respectively, followed by six rapid sand filters of 1.1 m.g.d. capacity each. Preceding each of the sedimentation basins was a mixing chamber of the over and under baffle type. The flow through the chamber preceding the small basin was 46.6 and through the other 20.6 feet per minute. In the small basin the flow was 2.14 and in the large 1.07 feet per minute. The raw water was and still is taken from the main channel of the Mississippi river and has the following characteristics:

Results in p.p.m., unless otherwise stated

Temperature	0°C.	to	32°C.
Turbidity	20	to	2600
Color	23	to	60
Total Alkalinity	80	to	200
Free CO_2	0.0	to	8.5
Total Hardness	90	to	220
pH	7.4	to	8.6
Counts on Agar	100	to	65,000
B-coli Index	1.85	to	91.9

This water was treated with chloramine and alum before entering the small basin and with a little more alum and all of the lime before entering the large basin. After the filters it was given a final dose of chlorine. The dosage of alum varied according to the turbidity and ranged from 2 to 10 g.p.g. The hydrated lime was fed through solution tanks in sufficient quantity to neutralize the free carbon dioxide and varied from 0.5 to 2 g.p.g. The total chlorine dosage ranged from 6 to 18 pounds per million gallons. The water works owned sufficient ground on both the north and south of the plant to provide for doubling the capacity of the plant.

REASONS FOR SOFTENING

Many have inquired as to the reason for softening a supply from the Mississippi river which averages about 150 p.p.m. total hardness. There were several factors which influenced the decision to erect a softening plant. First, there were some complaints from the consumers arising from the seasonal variation in hardness. Second, it was desired to remove an unsightly abandoned filter plant and clean up adjoining property due to the completion of the new "Quincy Memorial Bridge" just south of the water works property. Third, it was possible to provide work for many unemployed during the early part of the depression without involving the plant in any debts.

DESIGN OF SOFTENER

The softening plant was designed by Mead and Seastone of Madison, Wisconsin, in consultation with Mr. C. P. Hoover of Columbus, Ohio.

It was constructed as an addition to the south end of the plant on the ground originally intended for extension of the sedimentation basins. It consists of a chemical house and four basins; namely, two paddle type mixing basins, one clarifier, and a recarbonation basin. The mixing basins are about 17 by 26 feet in plan with a two blade paddle of 16 feet over all length, driven at a speed of 9.6 feet per second at the tip. They are arranged for either series or parallel operation. The clarifier is of the Dorr circular type, 80 feet in diameter with a tangentially fed center drop well and a collecting trough around the periphery. The sludge rakes are on trussed arms carried and driven by a central shaft; and sludge removal is through a center sump, by gravity, to the river. The recarbonation basin is fed from the bottom in one corner with collecting troughs on the two opposite sides. The diffusion grid is punctured with 1400 holes, $\frac{3}{32}$-inch in diameter. The depth of water in all basins, both old and new, is carried at about 19 feet.

The chemical house contains a hopper to receive lime by dump truck, Link Belt bucket conveyor to raise it to either of two large steel hopper bottom storage tanks of 1200 cubic feet capacity each, two Omega Universal dry feed machines suspended on Fairbanks-Morse scales, two Omega slakers, one Savage dry feed machine, one Dorrco Barnes Sludge pump, one Murray Iron Works coke fired marine boiler, scrubber, long leg trap, air filter, and one Gardner-

Denver double acting, single stage, horizontal air compressor. The flow sheet of the plant as it is now operated is:

		CAPACITY, GALLONS	RETENTION, HOURS
Baffled mixing chamber	Aluminum sulfate or iron sulfate	68,000	0.24
1st settling basin		380,000	1.40
Flume	Calcium oxide	30,000	0.11
1st paddle mixer	Sodium aluminate	65,000	0.25
2nd paddle mixer	Return sludge	65,000	0.25
Clarifier		691,000	2.50
Recarbonator	Flue gas	138,000	0.50
Baffled mixing chamber	Chlorine	111,000	0.44
2nd settling basin filters		736,000	2.70

SMALL SEDIMENTATION BASIN

When the softener was erected the center wall in this basin was cut through and the raw water applied to both sides of the wall at one end of the basin so that it now flows in one direction only, instead of around the end of the center wall as it formerly did. This reduces the theoretical flow, in this basin, to 1.07 feet per minute. This basin is operated as virtually so much dead space most of the time. When using iron sulfate there is, of course, no flocculation in this basin as the raw water contains no normal carbonates. With alum there may or may not be flocculation according to whether the alum dosage applied is sufficient to reduce the pH to the point where alum can floc out. It is not necessarily desirable to have much settling in this basin as sludge removal in the clarifier is more economical. Results so far have indicated that with raw water of moderate turbidity and average or high pH equal dosages of iron or alum give equal efficiency in the plant as a whole. This leaves the cost in favor of the iron and is the normal method of operation. With raw water of a high turbidity or low pH better conditioned water is obtained on the filters for equal dosage of coagulant if alum is used, so it is used when these conditions are prevalent. There has been one short test run applying the lime to this basin and reserving the alum for the paddle mixing basin with very gratifying results. As the plant setup does not allow easy accomplishment of this treatment, it will bear considerably more checking in the laboratory on various river conditions before attempting a long run on a plant scale.

PADDLE MIXING BASINS

With the exception of two short test runs the paddle mixers have been operated in series. On the only parallel runs made, the floc was well formed in the basin where the lime was added, but the water which had received alum only did not floc out well when mixed with the lime treated water.

The entire efficiency of the purification process is centered in the paddle mixers. A well formed floc in these basins will insure good removal of color, turbidity, bacteria, and hardness. The easiest, cheapest, and most certain way to obtain this satisfactory floc is to add sufficient lime to carry the softening well down into the magnesium. It is easy to do this with warm water of high magnesium content; but with cold water of low magnesium content it is undesirable to use the quantities of lime necessary to achieve this, because of difficulties in the later steps of the purification, which such excesses create. We are attempting to produce a final effluent of 70 p.p.m. total hardness, of which 40 p.p.m. is carbonate and 30 p.p.m. non-carbonate hardness; containing at the same time not more than 10 p.p.m. normal carbonates. In doing this, no soda ash is used as the non-carbonate hardness of the raw water is so low. With cold water or water of low magnesium content, there are two methods of obtaining good flocculation.

The most satisfactory floc is obtained by a large increase in alum or iron dosage. This method is objectionable from the standpoint of ice plants and boiler plants which are practicing additional softening without accurate laboratory control. While the total hardness of the final effluent can be maintained constant, the balance of carbonate to non-carbonate hardness is considerably disturbed. The addition of such quantities of alum or iron is also rather expensive.

The alternative method is the use of return sludge or sodium aluminate or at times, both. I choose, with the evidence at present available, to regard both of these materials as contact or catalytic agents, despite some opinions to the contrary. Whatever the mechanism of their reaction may be, their unquestionable effect is to force the lime reaction much further toward completion than it would otherwise go. This results in a final effluent of a lower alkalinity and at the same time, a lower pH than it is otherwise possible to produce. Of these two materials the sludge is cheaper and most effective, but is not sufficient at times to secure the desired results. Moreover, last spring when the water had warmed up to 18°C., a

taste developed which was described as musty. Discontinuance of the Sludge eliminated the complaints and no more sludge was used until the water had cooled down. This year there is a supply of activated carbon on hand to attempt to control this condition if it should again develop. As a flocculating agent, the sodium aluminate had no appreciable effect in the quantities used and all evidence indicates that it would be too expensive to consider for this purpose on this water. As a means of speeding up the lime reaction, it holds a preëminent place, being the only entirely satisfactory means of securing the degree of softening desired during adverse water conditions. If any more economical means can be found, the use of sodium aluminate will no longer be justified as the saving in other chemicals does not offset the cost of the aluminate.

CLARIFIER

The clarifier has been operated continuously and effectively, giving, on properly conditioned water, about 95 percent removal of turbidity. The sludge from it has averaged 5 percent solids.

RECARBONATOR

In the operation of the recarbonator, the policy has been to run the compressor at full speed. This is done because of the low pH which we wish to carry in the final effluent. There has been some difficulty with the holes in the diffusion grid clogging, partly from incrustation by the water on the outside and partly by a tarry material in the gas. This tar also caused trouble in the compressor before installation of an air filter to remove it and an iron dust which was passing through the scrubber.

LARGE SEDIMENTATION BASIN

Some attempts to obtain a secondary coagulation through the addition of chemicals in this basin have all been failures from the practical standpoint. There is also reason to believe that such a procedure would be uneconomical, as improved control in the paddle mixing basins has shown conclusively that the filter runs are not affected appreciably by three or four times the suspended solids normally carried in the effluent from this basin, but that they are reduced very materially by slight excesses of lime. Alum will not floc out at the pH of the recarbonated water. To secure efficient coagulation with iron, it is necessary to leave more normal carbonates than is desirable

in the effluent of this basin. Sodium aluminate, as has been pointed out, is too expensive. Consequently this basin has been operated without the addition of any coagulant. There is virtually no settling in it, but considerable agglutination of floc particles does take place. Bacterial removal, judged by the total counts on agar at 24 hours, has been very good and most of it has taken place by the time this basin is reached. The B. coli index has been somewhat higher than desired; apparently due partly to other strains of bacteria which do not give a positive test on eosin methylene blue agar and partly to the failure of, what should be entirely adequate, chlorination to completely remove this bacillus. For the past two months, the influent of this basin has been chlorinated sufficiently to leave the desired residual in the final effluent of the plant, without further chlorination. The result has been some improvement in the colon index. The water in this basin has practically no chlorine demand and there is also very little reduction of residual in passage through the filters. It is furthermore well established that the lower the pH of the water the more effective is a given dose of chlorine on the removal of the colon bacillus. A pH of 8.8–8.9 with the residual carried will insure practically complete removal of B. coli. This is one of the reasons for stressing the low pH which the use of sludge or aluminate makes possible.

FILTER OPERATION

The filters are very sensitive to a slight increase in lime. They give the longest runs (about 40 hours) when the pH of the applied water is about 8.9. Water of higher pH will quickly reduce the runs, due presumably to the deposits of carbonates on the sand. It is very difficult to maintain a pH this low with most of the raw water we treat and, as a result, the runs average about 30 hours. The washings are far from satisfactory, being very uneven because of clogged laterals in the strainer system; but this difficulty existed before softening.

COST

For those who are primarily interested in the business end of softening, it may be of interest to know that the total chemical costs have not increased much as a result of softening. A great deal more lime used, but it is quick lime instead of hydrated, and this factor helps costs somewhat. The big saving is in the coagulants due to the ad-

ditional settling time afforded by the clarifier. In only two months since softening has the average daily dosage of iron or alum equaled the minimum daily dosage of alum in the four years immediately preceding softening. The cost of all chemicals used averages between \$8.00 and \$9.00 per million gallons. These figures include rather large dosages of sodium aluminate used during the early trials with it and which have since been found to be unnecessary, so that better cost results may be looked for in the future. In discussing costs, it might be well to mention that the number of filter washes is only two-thirds of what it was before softening and the water per wash has remained the same.

COMPARISON WITH OLD IRON AND LIME PLANT

By way of historical reference it is interesting to note some records from the plant in 1907 to 1912 when they were using the iron and lime process for coagulation. That plant obtained an average reduction in alkalinity of 53.3 p.p.m. by the use of an average of 2.72 g.p.g. of lime during that period. That means an average of 0.05105 g.p.g. of lime used for each p.p.m. of reduction in alkalinity. The new plant has secured an average reduction in alkalinity of 97 p.p.m. by the use of 6.68 g.p.g. of lime. This is an average of 0.07072 g.p.g. of lime used for each p.p.m. of reduction in alkalinity. In other words, the new plant is using 38.5 percent more lime per p.p.m. of alkalinity removed than the old plant used. This illustrates very forcibly the cost of removing that part of the hardness for which one must use excess doses and then removing the excesses by recarbonation.

(Presented before the Illinois Section Meeting, April 19, 1933.)

MUNICIPAL WATER SOFTENING

By W. H. Walker

(Engineer, Etobicoke Township, Islington, Ontario, Canada)

Perhaps the old maxim that "Cleanliness is next to Godliness" has had a great deal to do with the ever-increasing demand for soft water. Somewhere deep down in our innermost beings we have an inborn desire for cleanliness which in turn creates the necessity of using water in the process of cleansing. Soap has been found by experience, as being an excellent aid to this process and it is the difficulty of obtaining the necessary lather, which has invited the use of various means of reducing the soap-consuming power of natural waters.

Before obtaining a lather with any water and soap, the previously-mentioned calcium and magnesium salts have to be rendered inert. This is done by some of the soap uniting with these compounds, forming insoluble sticky curds which tend to adhere to all things with which they come in contact. It is this substance which forms the "ring around the bath tub" after bathing.

Mr. Charles P. Hoover (1) states that lime costing ½ cent will soften as much water as will 20 pounds of soap costing from $2.00 to $3.00. From these data, it can be readily seen, that a considerable saving could be made in the use of soap if lime were used to soften the water.

Many figures have been given as to the savings made by softening water. Some of these have been tabulated below:

Author	Soap consumed to soften 1000 gals. water, 1 p.p.m., in pounds	
	U. S. gals.	Imp. gals.
Whipple (2)	0.215	0.258
Buswell (3)	0.10	0.120
Pauline Snyder (4)	0.14	0.172
Foulk (5)	0.2	0.240
Average		0.198
		or say 0.2 lbs.

Note: The variation in the figures obtained by different investigators is probably due to the varying of percentage of water in commercial soaps.

Taking this average, and using Prof. Whipple's figure that an average of 1 gallon per person per day is used for washing, table 1 has been made in order that the reader might interpolate the savings to be made in terms of the water he uses.

Prof. A. M. Buswell states that he estimates 1 ton of soap is wasted every day in a community of 40,000 people using water of 300 parts per million hardness.

A second reason for the desirability for soft water is the saving made due to the reduced scale in boilers and in heating plants. Most large commercial concerns soften water for boiler purposes alone.

TABLE 1

RAW WATER HARDNESS, P.P.M.	HARDNESS REDUCED, P.P.M.	HARDNESS REMOVED, P.P.M.	LOSS IN SOAP PER ANNUM		
			Per capita, pounds	Per family of 5 members, pounds	Per family, dollars
400	80	320	23.4	117	35.10
350	80	270	19.7	98.5	29.55
325	80	245	17.9	89.5	26.85
300	80	220	16.05	80.3	24.09
250	80	170	12.4	62.0	18.60
200	80	120	8.75	43.8	13.14
150	80	70	5.1	25.6	7.68
125	80	45	3.28	16.4	4.92
100	80	20	1.46	7.3	2.19
80	80	0	0.0	0.0	0.0

Average family of 5 used.
One gallon per capita equals 1825 gallons per family per year.
Average cost of soap 30 cents per pound.

The savings made by this process are proportionally just as great in the small household heating equipment as in the large commercial units. It is hard to estimate these savings. In a water containing 300 p.p.m. of hardness there are approximately 2400 pounds of scale-forming material per million gallons of water. The water service committee of the American Railway Engineering Association estimates that the costs of boiler operation is increased 13¢ for every pound of scale in boiler water used.

Professor Schmidt (6) of the University of Illinois has compiled the following table on heat losses from a series of experiments:

COMPOSITION OF SCALE	THICKNESS, INCHES	PERCENT LOSS	POUNDS OF COAL WASTED PER TON USED
Hard—mostly carbonate...........	$\frac{1}{50}$	5.4	100
Soft—mostly carbonate...........	$\frac{1}{32}$	7.2	140
Hard—mostly sulphate............	$\frac{1}{25}$	9.3	180
Hard—mostly sulphate............	$\frac{1}{20}$	11.1	200
Soft—mostly sulphate............	$\frac{1}{16}$	10.8	220
Soft—mostly carbonate...........	$\frac{1}{11}$	15.0	300
Hard—mostly sulphate............	$\frac{1}{8}$	15.9	320

A third reason for softening water is the saving in the wear and tear of fabrics during washing. Miss Snyder (4) in her thesis on this matter estimates that clothes washed in soft water have an increased life of from 25 to 100 percent. She also states that the time required to launder clothes is 50 percent less in soft water than in unsoftened water.

A fourth reason for a municipal soft water supply is the elimination of duplicate plumbing, soft water cisterns pumps, etc. This perhaps is more true where the water supply is very hard.

RELATION OF WELL WATER SUPPLIES TO SOFT WATER

During the recent years, there has been a steady increase in the use of deep wells as a source of municipal water supply as evidenced by figure 1 for the increase in the Province of Ontario.

Deep well water supplies are usually hard with often a considerable amount of iron in the ferric or ferrous state. Where such supplies are not obtained from badly fissured rock, they are usually bacteriologically pure, and need little or no chlorination.

All of these items lend themselves very readily to the use of some softening treatment. Iron has been successfully removed by the process used in softening with very little additional cost of treatment. The saving made by the elimination of the chlorination or other purifying treatments will also go a long way towards the cost of softening.

A list of the well water supplies in Ontario and some of their characteristics is shown in table 2.

ETOBICOKE TOWNSHIP'S PROBLEM

To obtain a proper grasp of Etobicoke Township's situation, it will be necessary to give a brief sketch of the conditions leading up to the installation of the water softening plant.

At the inception of the Township's Water Department, several areas were created in the southern section of the municipality almost simultaneously with the exception of Area #1, shown on figure 2. The chief source of supply came from New Toronto through the mains of Mimico to our Church St. Pump-House. Here the pressure was boosted and the water delivered to the various other areas

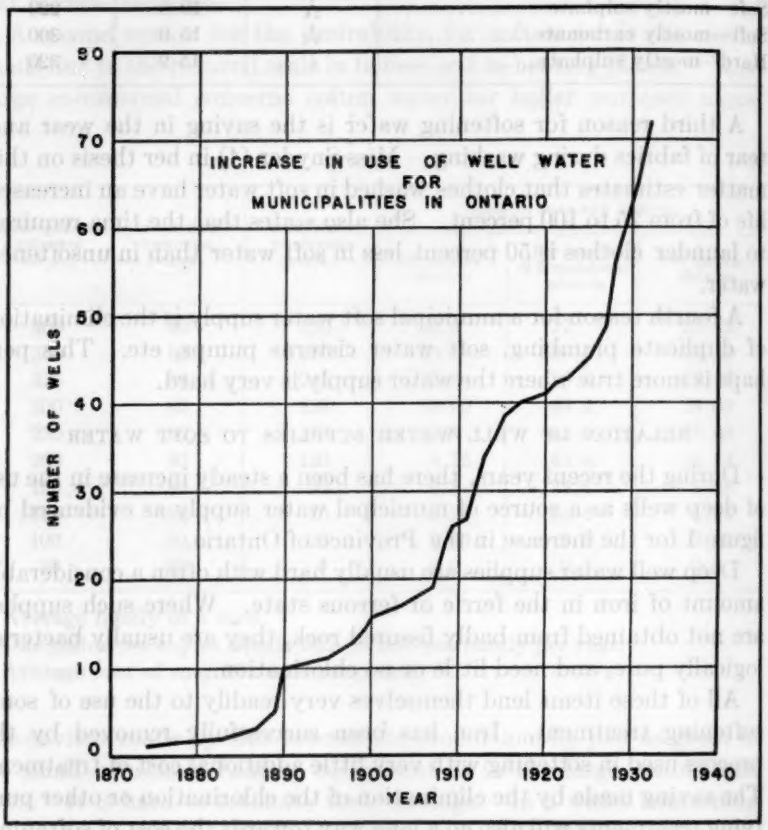

FIG. 1

in the township. The waterworks system has grown very rapidly from its inception in 1923 to the extent of 62 miles of mains in 1932 and since the main in Mimico was not designed to take care of Etobicoke's needs, the rapid growth soon over-loaded this main to such an extent that often times the booster pumps would be drawing a vacuum. This situation became so serious that in 1931 and 1932,

TABLE 2

Characteristics of well waters in Ontario

YEAR	MUNICIPALITY	SOURCE OF SUPPLY	AVERAGE TOTAL HARDNESS	REMARKS
1930	Almonte	Wells	278.5	
1931	Arthur	Wells	194	
1888	Aurora	Wells	210	
1930	Aylmer	Wells	67.3	
1898	Barrie	Wells	235	
1927	Blenheim	Wells	142	
1928	Blind River	Wells	245	
1908	Bothwell	Wells	280	Shallow
1895	Bracebridge	Wells	82	
1930	Bradford	Wells	200	
1911–28	Brampton	Wells	222	
1931	Burk's Falls	Wells	105	
1930	Capreol	Wells	44.5	
1909	Chesley	Wells	700	
1909	Clinton	Wells	304	
1913	Cochrane	Wells	322	
1930	Courtwright	Wells	159	
1908	Elmira	Wells	321	
1926	Elmvale	Wells	146	
1890–1930	Essex	Wells	432	
1913	Fergus	Wells	523	
1926	Forest	Wells	132	Shallow
1890	Galt	Wells	416	
1928	Glencoe	Wells	54	
1932	Guelph	Springs and Wells	296	
1912	Harriston	Wells	230	
1916	Hespeler	Wells	464	
1931	Ingersoll	Springs and Wells	304	
1887	Kitchener	Wells	321	Numerous
1915	Lambeth	Wells	230	
1890	Leamington	Wells and Lake Erie-Wells	316	
1903	Listowell	Wells	236	
1909–28–21	London	Springs and Wells	290	
1930	Lucknow	Wells	265	
1927	Midland	Wells and Spring Creek	194	
1908	Mildmay	Wells	292	
1920	Milverton	Wells	912	
1900	Mitchell	Wells	264	
1898	Mount Forest	Wells	319	
1932	Nigigon	Wells	250	
1914	Norwich	Wells	220	

TABLE 2—*Concluded*

YEAR	MUNICIPALITY	SOURCE OF SUPPLY	AVERAGE TOTAL HARDNESS	REMARKS
1913	Otterville	Wells	255	
1908–28	Palmerston	Wells	320	
1913	Parkhill	Wells	128	
1900	Penetanguishene	Springs and Wells	172	
1912–15	Ridgetown	Wells	67	
1899	St. Marys	Wells	189	
1874–90	St. Thomas	Kettle Creek and Wells	293	
1923	Seaforth	Wells	292	
1889	Shelbourne	Wells	280	
1907	Simcoe	Wells	189	Shallow
1907–28	Stouffville	Springs and Wells	208	Shallow
1883	Stratford	Wells	277	
1928	Strathroy	Wells	253	Shallow
1914	Tottenham	Wells	229	
1890	Walkerton	Wells	708	
1925	Waterdown	Wells	236	
1925	Wateford	Wells	—	Shallow
1921	Watford	Wells	173	
1932	Weston	Wells	300	
1912	Wingham	Wells	303	
1931	Woodstock	Springs and Wells	120	
1917	New Liskard	Wells	650–790	450′ deep

on several occasions, portions of the Municipality were without water for several hours during the dry season.

Requirements

Investigations for a further supply were commenced in 1931. Careful study of the consumption shown on figure 3 and the growth in population, lead us to believe that the requirements for the next 5 years would be under 1,000 I.G.P.M. or approximately $1\frac{1}{2}$ m.g.d. With this consumption as a basis, two favorable schemes seemed to present themselves.

Scheme I

The first scheme for consideration was one for which our present system was originally designed and involved the laying of a 16-inch main on Kipling Ave. directly from New Toronto. From here, it would be boosted in pressure and distributed through the system in

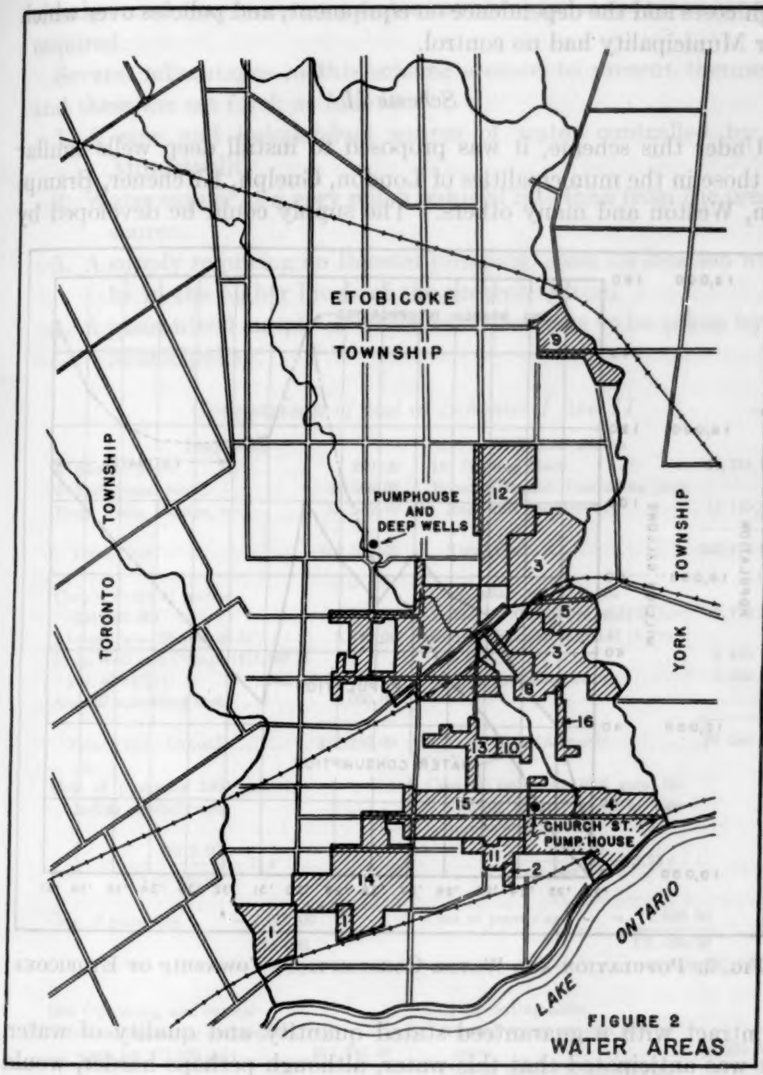

FIG. 2

existing large lateral mains. The scheme would involve the construction of a long length of large main, a new Booster Pump-House, and another elevated tank to take care of emergencies. The source of water supply would still be from New Toronto which would entail

high costs and the dependence on equipment, and policies over which our Municipality had no control.

Scheme II

Under this scheme, it was proposed to install deep wells similar to those in the municipalities of London, Guelph, Kitchener, Brampton, Weston and many others. The supply could be developed by

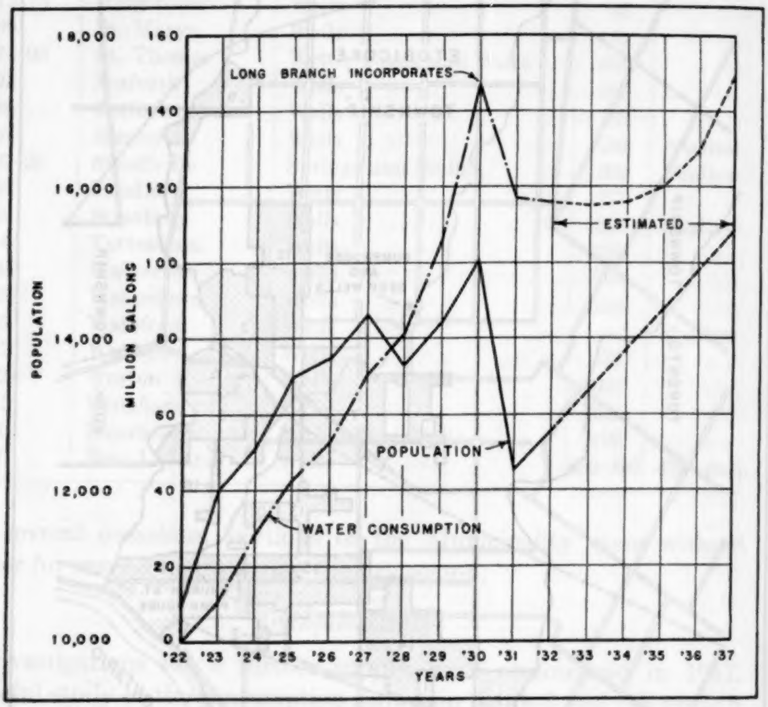

FIG. 3. POPULATION AND WATER CONSUMPTION, TOWNSHIP OF ETOBICOKE

contract with a guaranteed stated quantity and quality of water. It was anticipated that this water, although perhaps harder, would require no chlorination or filtering and it appeared from tests made for well locations, that the length of trunk main to be constructed was very much shorter than in scheme # 1. Some doubts seemed to be put forward as to the uncertain nature of the supply and of the future possibilities in connection with the same. Further test holes drilled in the area of the proposed locality of the well site, were suffi-

ciently convincing to assure a water supply of twice the rated capacity required.

Several advantages in this scheme seemed to present themselves and these are set forth as follows:

1. A new and independent source of water controlled by our Municipality.
2. Water supply at a very much reduced rate than from the present source.
3. A supply requiring no Booster pumping, since its location would be in the higher levels of the present system.
4. A guaranteed supply of water with few risks to be taken by the Municipality.

Comparison of cost of Schemes I and II

Deep wells		*Booster station*	
8″ Shaver Main	850.00	16″ Kipling Main	44,234.05
6″ 2nd. Conc. Main	25,300.00	Booster Station (including pipe lines and equipment)	19,140.00
Deep Wells, Pumps, etc	34.500.00		
Total Cost	$60,650.00	Total Cost	$63,374.05
Corp's. share of mains ($25,505.00)		Corp. share of 16″ main ($33,183.05 (20 yrs. @5½%))	2.770.00
Annual rate (20 yrs. @ 5½%)	2,140.00	Booster Station ($19,140 (5 yrs. @ 5½%))	4,480.00
Deep Well and Pumps ($34,500 (5 yrs. @ 5½%))	8,070.00	Annual operating costs	2,000.00
Annual operating costs	2,000.00		
Total Cost (Annual)	$12,210.00	Total Cost (Annual)	$9,250.00

Cost of pumping 1000 gals. including capital costs

$$\frac{12210.00}{175,000.00} = 7\tfrac{1}{4}¢$$

Cost of pumping $= \dfrac{20000.00}{175,000} = 1.15¢$ per M. Gal.

Cost of pumping 1000 gals. including capital costs of new pumps and mains

$$\frac{9250.00}{175,000} = 5.25¢$$

Cost of pumping $= \dfrac{2,000.00}{175.000.00} = 1.15¢$ per M. Gal.

1931 Operating and capital:		1931 Operating costs:	
Annual operating and capital costs for 175,000 gals	$12,210.00	Annual operating and capital costs	$9,250.00
		Cost of water 175,000,000 gals. @ 15¢	26,250.00
			$35,500.00

The estimated figures show that by use of the deep well system, there would be a net annual saving of:

(1) $23,290.00 including capital costs.

(2) $26,250.00 considering cost of pumping only.

From the fore-going figures, it may be seen that the approximate capital costs for each scheme were about the same, and the savings may seem to be principally due to the fact that in one case, water had to be purchased at 15¢ per 1000 gallons, while in the other case, the water was delivered at the plant without cost. The savings made could be roughly fixed at 15¢ per 1000 gallons or between $20,000 and $25,000 annually.

Accordingly, a Contract was awarded to the Jordon-Roberts Sales Ltd., Brantford, for the supply of 1,000 I.G.P.M. or 1,440,000 g.p.d. for the sum of $23,500. This supply was to be obtained from two wells conveniently located near each other and the site of this location was to be approved by the writer.

DRILLING AND TESTING WELLS

A temporary location was decided upon and near this, the Contractor drilled some 5 other test holes to determine the extent of the water-bearing strata from which the source of supply was to be obtained. A careful log of the soil conditions through which each well passed, was taken. This revealed the following general information:

DEPTH, FEET	TYPE OF STRATA	WATER FROM THE SURFACE, FEET
0–10	Sand	5
10–40	Quick-sand	
40–45	Sand and clay	2
50–100	Gravel, sharp sand	1½ above

From these tests, calculations were made as to the probable extent of the water-bearing strata and an estimate of the water infiltration made.

WELL CONSTRUCTION

Blank casings were carried down to the top of the gravel-bearing strata approximately 45 to 50 feet and then a second casing surrounded by properly sized gravel and equipped with a molybendum iron screen, was constructed to a depth of approximately 80 feet. Water was pumped by two Peerless turbine pumps, one operated by a 20 and one by a 15 H.P. electric motor.

To insure of an adequate supply, these wells were operated continuously night and day for 30 days. During this period, accurate

checks on the water pumped, power used, and drawn-down in the wells were kept.

EXCESS IRON ENCOUNTERED

Before the test of the wells had been completed, it became quite apparent that the iron content of the water would be too high if generally used without some treatment.

The analysis of the water made by the Department of Health would show that the iron content should be reduced by 1.1 p.p.m. and that the hardness of the water was much the same as that of many other well supplies in the Province of Ontario. Much discussion of this problem lead to direct experiments being made with a view to reducing the iron content.

The iron appeared to be in the ferrous state, and it was thought aeration followed by sedimentation might be sufficient to precipitate the iron. A portion of the water was by-passed and sprayed through garden hose nozzles, over a series of baffles. On the other well, an experimental aero-mix apparatus was installed. In both cases, analyses were made of the aerated water after it had settled and it was found to contain approximately 0.8 p.p.m. iron from either device. Further tests revealed that aeration alone would not be sufficient to remove the iron content as the floc formed was very light and took a long time to precipitate. Accordingly, lime was added, and this proved to be a satisfactory method of adequately treating the water.

IRON REMOVAL LEADING UP TO WATER SOFTENING

Investigations were made, revealing that practically all types of iron removal equipment would necessitate a chemical feed apparatus, some type of aerater, settlement chambers, and pressure filters. The capital cost of such equipment would be very high, ranging from $12,000 to $20,000. The treatment charge would run in the neighborhood of 1 to 1½¢ per 1000 gallons.

With practically the same equipment, and the addition of some lime, not only the iron could be removed, but also a great deal of the hardness of the water. The treatment charge for softening and iron removal appeared to be in the neighborhood of 2 to 2½¢ per 1000 gallons.

To coördinate the studies made and to obtain some definitely fixed prices, tenders were called for equipment to treat the water (not including buildings) based on four methods:

1. Iron removal only.
2. Iron removal and softening by chemical precipitation.
3. Iron removal and softening by base exchange.
4. Iron removal and softening by a combination of methods 2 and 3.

The contractor was asked to give a guaranteed price of all necessary equipment, a guaranteed price per 1000 gallons for chemicals

TABLE 3

Township of Etobicoke—analysis of water

(Results in p.p.m.)

C.W. 45	RAW WATER	TREATED WATER
Total solids	431.2	400
Loss on ignition	186.4	185
Alkalinity	294	300
Soap consuming power	322	80
Silica	1.2	1.2
Iron and aluminium (oxides)	2.2	0.50
Calcium (Ca)	81.75	20.50
Magnesium (Mg)	21.06	5.25
Sodium and potassium	19.9	71.00
Sulphates (SO_4)	18.43	18.43
Chlorides (Cl)	18	18.0
Nitrogen as:		
Free ammonia	0.062	0.020
Alb. ammonia	0.002	0.042
Nitrites	None	Nil
Nitrates	1.6	1.6
Oxygen consumed	2.0	2.0
Iron (Fe)	1.4	0.2
Hydrogen ion concentration, pH		7.2
Dissolved oxygen		1.5

used in treatment, and an estimate of the size and cost of the buildings, concrete settling chambers, etc. required for the plant.

The information in table 4 was taken from the tenders submitted.

In view of the facts that iron removal alone would cost nearly as much as softening, and the fact of the savings to be obtained from the use of softened water, resulted in the decision to award a contract to the Permutit Company of Canada, for the installation of a zeolite down-flow softening system. The contract stipulated a guaranteed quantity of water for a period of one year and the guar-

antee that the operating costs would not exceed 2.4¢ per 1000 gallons based on salt at $8.10 per ton f.o.b. the plant.

DESIGN AND WATER TREATMENT EQUIPMENT

The treatment plant was designed for four welded steel tanks 12 feet x 9 feet diameter. These tanks were placed on end in the

TABLE 4

Quotations received for treatment plant

CONTRACTOR	METHOD #1 IRON REMOVAL ONLY	METHOD #2 IRON AND SOFTENING BY LIME-SODA	METHOD #3 IRON AND SOFTENING BY ZEOLITE	METHOD #4 IRON AND SOFTENING BY COMBINATION
A	No quotation	E—$6,537.00 B—$35,000 T—5¢ Building 161′ x 40 Water to be at 50°C.	E—$20,937 B—$8,200 T—5¢ Down-flow type Wash water to be from mains	E—$13,913 B—$5,109 Up-flow type Iron removal not guaranteed
B	E—$14,950 B—$5,000 Four—8′ x 6 pressure filters required	E—$24,950 B—$31,000 Building 52 x 70 x 12 Mixing tank 10 x 10 x 12	E—$35,450 B—$6,000 T—1½¢ to 1¾¢ 4—Pressure filters 8 x 16 4—Softening units 8 ft. dia.	E—$35,950 B—$32,000 Building 140 x 45
C	E—$10,850 B—$8,600 T—1¼¢	E—$25,160 B—$7,900 T—2.8¢ B—not including house for large tanks	E—$15,330 B—$7,800 T—2.4¢ Building 53 x 18 x 14	No quotation

E = Equipment; B = Buildings; T = Treatment cost.

building before the walls were constructed. The strainer system in the bottom is set in cement. Upon this, a small amount of screened gravel is placed and the balance of the tank is filled with greensands (zeolite).

The whole plant is designed for 1000 Imp. Gallons per minute including by-passed water and all regeneration. The rate of softening is designed for 3.8 G.P.M. per square foot area, or 244 gallons per minute per unit.

The capacity of each unit between regeneration is 889,000 grains of hardness removed or 43,600 gallons of water softened.

The salt required for each regeneration is designed at 356 pounds.

The back-wash rate was set at 6 gallons per minute per square foot.

OPERATION DATA

The Etobicoke Waterworks Plant was officially opened on November 16, 1932, but water was not actually placed into the system until about December 1st. It is therefore rather difficult to obtain any fair figures about the operating costs in such a short time.

Soon after the inauguration of the new water system, many complaints were received about the bad odor and rusty water found on all dead ends. This grew to such proportions, that grave concern was aroused.

To further study the matter, the series of tests shown in table 5 were taken at different points throughout the township with a view to studying the conditions in the whole system.

The analyses show certain irregularities in chlorides and hardness, which were due to the day to day variation in the composition of the water delivered from the plant. This variation has now been considerably lessened, with our greater experience in operation.

During the period covered by these analyses, an ever-increasing number of complaints due to the rusty color of the water and the staining of porcelain from dripping faucets, were received. These facts coupled with the observation that the water when freshly drawn off was clear, but soon became cloudy on standing, pointed to the presence of considerable iron in the ferrous state. Some instances were noted where the iron in the tap water had increased to 1.6 p.p.m., whereas the treated water leaving the plant contained only 0.1 to 0.2 p.p.m. These observations showed the active nature of this water in attacking the mains.

It was thought that an increase in the amount of free oxygen in the water might check or eliminate this iron pick-up; more particularly as a series of analyses showed that in each instance where the iron content was excessive, the free ozygen content was zero.

A change in piping was therefore made, whereby the water from the softeners was made to spill from a height into the reservoir, and after the lapse of several days further analyses were made. These are given in table 6, along with analyses made immediately prior to this change.

The results show a remarkable reduction in the amounts of iron, and indicate that the increase in dissolved oxygen has entirely eliminated the iron pick-up. In fact, the analyses show that, in some in-

TABLE 5
Analytical results in various parts of township

LOCATION	DATE	TAP	pH	O_2	CO_2	Fe	Cl	HARDNESS	REMARKS
W. W. Plant	Dec. 22	Raw	7.1	0.0	17.5	1.5	10.7	300	Cloudy on standing
	Dec. 30		7.2	0.0	15.0	1.6	14.0	301	Cloudy on standing
	Jan. 11		7.1	0.0	14.6	1.5	13.5	331	Cloudy on standing
W. W. Plant	Dec. 22	Cold	7.2	1.0	15.0	0.0	20.0	89	Over-run method
	Dec. 30		7.2	0.87	13.0	0.0	15.0	95	Over-run method
	Jan. 11		7.1	0.0	14.5	0.15	14.5	94	By-pass method
Old Mill, Kingsway	Dec. 22	Cold	7.2	1.30	14.0	0.0	23.2	97	
	Dec. 30		7.2	1.16	13.4	0.1	21.0	96	
	Jan. 11		7.1	1.15	15.7	0.2	21.5	97	
School, Lambton	Dec. 22	Cold	7.3	1.45	9.0	0.0	21.3	94	
	Dec. 30		7.2	1.09	10.0	0.0	19.0	97	
	Jan. 11		7.1	1.30	14.4	0.1	18.8	63	
School, Alderwood	Dec. 22	Cold	7.3	1.15	15.0	0.2	20.0	108	
	Dec. 30		7.2	0.80	12.0	0.7	21.0	91	
	Jan. 11		7.2	0.60	14.8	0.4	21.2	83	
School, Humber Bay	Dec. 22	Cold	7.2	1.30	16.0	0.0	19.5	92	
	Dec. 30		7.1	1.02	12.4	0.7	20.0	100	
	Jan. 11		7.2	1.3	15.6	0.45	24.5	67	
H. Dilworth, Islington	Dec. 22	Cold	7.1	1.45	13.5	0.15	20.3	86	
	Dec. 30		7.2	1.01	12.0	0.10	15.0	65	
	Jan. 11		7.2	0.7	14.8	0.10	15.2	42	

stances, the iron content is now *less* at the customer's tap than at the waterworks plant, indicating a *deposition* in the mains.

Staining of porcelain, and complaints as to color, odor and taste of the water were eliminated, within the month following the above indicated change in operation of the plant.

Apparently what happened was that the water previously used in the system was from Lake Ontario and therefore was saturated with oxygen. This had deposited certain corrosions of ferric oxide on the pipes. The new water being free from oxygen attacked this ferric oxide, absorbing one of the molecules of oxygen and reducing

TABLE 6

Analytical results at various taps

LOCATION	DATE	TAP	OXYGEN	IRON	REMARKS
W. W. Plant	Jan. 14	Raw	0.00	1.50	
	Jan. 20	Raw	0.00	1.20	
W. W. Plant	Jan. 14	Treated	0.50	0.20	No aeration
	Jan. 20	Treated	6.10	0.15	With aeration
S. E. Watson, Islington	Jan. 14	Cold	0.00	1.6	Very cloudy
	Jan. 20	Cold	3.50	0.20	Clear
H. M. Dilworth, Islington	Jan. 14	Cold	0.20	0.30	Clear
	Jan. 20	Cold	5.00	0.08	Clear
W. H. Walker, Islington	Jan. 14	Cold	0.44	0.30	Cloudy
	Jan. 20	Cold	3.00	0.18	Clear
Old Mill, Kingsway	Jan. 14	Cold	0.06	0.15	Cloudy
	Jan. 20	Cold	3.06	0.03	Clear
School, Lambton	Jan. 14	Cold	0.30	0.10	Clear
	Jan. 20	Cold	5.14	0.08	Clear
School, Alderwood	Jan. 14	Cold	0.00	1.00	Very cloudy
	Jan. 20	Cold	2.30	0.15	Slight cloudiness
School, Humber Bay	Jan. 14	Cold	0.10	0.20	Slightly cloudy
	Jan. 20	Cold	4.10	0.05	Clear
A. Lyttle, Humber Bay	Jan. 14	Cold	0.00	1.20	Very cloudy
	Jan. 20	Cold	3.34	0.05	Clear

the scale to ferrous oxide. Thus water, leaving the plant free from iron, reached the customer with large amounts of ferrous oxide, which is soluble in water, and in addition, many other foreign minerals found in the old pipe corrosion. The addition of air to the water at the plant was sufficient to stabilize and neutralize any effect on the old scale.

Salt consumed

The salt brine is pumped from the main storage tank to a small measuring tank in the softener room. From here, it is injected with raw water into the softeners in definite measured quantities. Every day, the density of the brine solution is checked so that the right dosage per regeneration may be determined. The brine is nearly always at complete saturation except when the salt in the storage is low. The system was designed on 0.4 pound of salt per 1000 grains of hardness removed, but this has been reduced to 0.31 pound per 1000 grains. Salt is actually being purchased for $7.35 per ton at the plant.

By-passed water

The water treated is softened to 0 degrees of hardness while the desired amount is 80 p.p.m. In obtaining the desired hardness, two methods have presented themselves, that of over-running the softeners and that of by-passing raw water.

When the zeolite has been exhausted and will no longer produce soft water, it will continue to reduce all of the iron from the water for at least a quantity equal to the amount of water previously softened. The mixing of 250 gallons of water per minute at 320 parts per million of hardness, with 750 gallons per minute at 0 degrees, will produce 1000 gallons of water per minute at 80 p.p.m. This was made very easy with four softening units by over-running one unit while the others were producing soft water. Regenerating was accomplished by increasing the flow on the other units.

By this method, the iron in the completed water was entirely removed, but it was found to be difficult to maintain a water of uniform softness since the quantity of water softened at each run varied slightly. In addition, since all the water passed through the zeolite, their capacity was reduced, and their life decreased.

By-passing some of the raw water for mixing with the treated, only presented the problem of holding the iron content down to below 0.3 p.p.m. For one month, a combination of over-running and by-passing was used in order to maintain required minimum iron content. Since the aeration of the water, by letting it drop from the softeners into the reservoir, a better opportunity for controlling the proportions of mixing has been obtained. By-passing has therefore been used with great success, the proportion at the present time being about 18 per cent of the total water put into service.

Back wash and rinse water

At each regeneration, the zeolite bed is back-washed at the rate of 5 gallons per minute per square foot, then steeped in salt brine and rinsed. This, together with any other wastages, consumes about 16 per cent of the water put into service.

This figure is high, as some difficulty was experienced in obtaining an adequate loosening-up of the bed. A few weeks ago, the pipe receiving the back-wash water was raised to allow for a greater expansion of the bed, and the back-wash rate increased to 6 gallons per minute per square foot while the length of time was decreased.

By this method, it is hoped to reduce the number of times of back-washing to once every third or fourth regeneration. Very little deposit is left on the bed and the back-wash is really a method of keeping the bed from packing.

Water used for the above-mentioned operations should be between 10 and 12 percent.

Meters

The water discharged from the wells, and service pump is metered by three electric orifice meters, purchased from the Dominion Fow Meter Co. Each meter records, integrates, and gives the flow of the water in gallons per minute.

Each softener unit is also equipped with a 4-inch Trident compound alarm meter, so that the water softened is accurately measured.

POWER CONSUMED

Owing to the fact that a great many of Etobicoke's customers are market gardeners, golf clubs, etc., the summer consumption is very much higher than the normal consumption. Due to this and the flexibility of the plant, considerable power saving is available.

When the equipment was first put into operation, both the service booster pump and the two well pumps were operated together, creating a demand of 165 horse power. By operating the wells alone, filling the reservoirs with 100,000 gallons of treated water and then operating the booster pump alone to put this into service, the power demand was reduced to 133 horse power.

The savings made have been set forth in the comparison of the typical bills in table 7.

Since it requires nearly 250 minutes to treat and put 100,000 gallons of water into service the method above suggested would not be

possible when the demand reaches over 400 gallons per minute per day. This is only 40 percent of the designed capacity, but will only be exceeded in the summer months for a period of several years.

Stand-by equipment

Provisions have been made for a diesel driven generator and pump combined on one shaft with a clutch to disengage the pump. Owing to financial conditions this development will have to be evolved later. At the present time, a stand-pipe containing 440,000 gallons and a connection to the mains at Long Branch and Mimico, are the only sources of supply during a break-down.

TABLE 7

Comparison of bills for power

	BILL NO. 1 (165 H.P. DEMAND)		BILL NO. 2 (133 H.P. DEMAND)	
Service charge	(148.4 H.P. @ $1)	$148.40	(119.7 H.P. @ $1)	$119.70
	(5535 K.W.H. @ 1.8¢)	99.63	(4450 K.W.H. @ 1.8¢)	80.10
	(5535 K.W.H. @ 1.1¢)	60.88	(4450 K.W.H. @ 1.1¢)	60.88
	(3780 K.W.H. @ 0.33¢)	12.47	(5950 K.W.H. @ 0.33¢)	19.64
Gross		$321.38		$268.39
Local discount 10%		32.14		26.84
		$289.24		$241.55
Prompt payment 10%		23.92		24.15
Total		$260.32		$217.39
Net Monthly Saving				$42.93

ATTENDANCE

At the present time, with a daily consumption of 300,000 to 400,000 gallons per day, one man is all that is necessary. We are contemplating additional help in the peak period. The plant is started at seven P.M. and continues to operate all day. At night the pressure is maintained from the stand pipe. A close supervision of the operation is kept, which requires continuous chemical tests for iron hardness, chlorides, etc. All records are tabulated and a report made out every day.

UNIT OPERATING COSTS

As previously stated, the figures given below only serve to show what might be done in regard to a municipal water softening plant. The writer is quite sure that, when the final adjustments to the operation, etc. have been completed, a considerable reduction in the costs will be made.

Based on our present annual consumption of 125,000,000 gallons per year, the cost of water per 1000 gallons put into service is 13.0 cents.

This figure is arrived at as follows:

	cents
Attendant's wages	1.2
Heating	0.2
Salt	2.3
Power	2.5
Total per 1000	6.2
Fixed charges (Bldgs. and land)	2.1
Meters, pumps, equipment	4.7
	6.8

TABLE 8

Comparison of chemical and other costs

LIME-SODA PROCESS		ZEOLITE PROCESS	
Hydrated Lime, 208 tons @ $14.00	$2,940.00	Salt, 371 tons @ $8.75	$2,876.25
Soda Ash, 20 tons @ $45.00	900.00	Attendance	1,500.00
Alum	865.00	Heating	250.00
Coke, 104 tons @ $10.00	1,040.00	Power	3,125.00
Attendance	1,500.00		
Heating	250.00		
Power	3,125.00		
Total Operating Charges	$10,620.00	Total Operating Charges	$7,751.25

ANNUAL SAVINGS

In order to determine the saving made by the use of zeolite softening, a comparison has been made, using estimated figures for the lime-soda treatment. The analysis of water was taken as:

	p.p.m.
Soap consuming power	322
Alkalinity	294
Magnesium hardness	87

The results are shown in table 8.

These figures assume that the only differences are in the chemicals for treatment. The other savings to be made are difficult to estimate since no lime-soda plant has been designed to meet the local

conditions. The calculations, however should satisfy the reader that economical results can be had by the use of zeolite softening. The chief factor in the cost of lime-soda is the lime, which is quite costly around Toronto. Columbus, Ohio, purchases this chemical for less than $5.00 per ton.

Sludge disposal for Etobicoke would also have been a large problem. Even the City of Columbus finds it difficult to dispose of the sludge in its large river.

Soap savings

The savings in soap are perhaps very small to the individual family, but nevertheless amount to an amazing figure when taken as a whole.

As previously stated, the average family will soften with soap about 1825 gallons of water per year in the laundry, kitchen and bath. This would mean our 2500 families would consume 4,560,000 gallons annually for this purpose, which doer not seem exaggerated in the face of a total consumption of approximately 120 million gallons annually. From our previous figures, that 0.2 pound of soap are required to soften 1000 gallons of water, 1 p.p.m., the Etobicoke customers now using a water 40 p.p.m. softer than previously, save some 36,480 pounds of soap per year.

Other savings

The savings made by the increased efficiency of heating units, the increased life of fabrics washed in soft water, the decrease in the repairs to plumbing, and the decreased expenditures required in industry are rather hard to estimate. The bureau of laboratories of the Michigan Department of Health, in Bulletin #15, has given figures which very nearly cover our conditions. The decrease in the hardness is nearly 25 percent, but the increase in the number of families is also 25 percent. The writer is therefore quoting these figures to support his own beliefs in the savings, made by the use of soft water.

1. Cost of extra soap to neutralize hard water	$18,400.00
2. Cost of repairs in plumbing	8,000.00
3. Cost of boiler compounds	740.00
	$27,140.00
4. Plus 10% hospitals, schools, public bldgs, etc.	2,714.00
Total tangible cost per year	$29,854.00
Cost per family per year	$11.90

CONCLUSION

Since Etobicoke Township's system is the first municipal zeolite water softening plant in Canada, much interest will be taken in the data gathered from time to time. Every effort will therefore be made to keep an accurate check on all items in order to compare the operations of this plant with similar ones in United States.

In the preliminary investigations before the installation of the plant, the writer would like to acknowledge the invaluable assistance given by Norman J. Howard, of the Toronto Filtration Plant, Charles P. Hoover, of Columbus, Ohio, A. E. Berry and Mr. DeLaporte of the Ontario Provincial Board of Health, and Mr. E. Nordelle of the Permutit Company.

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WATER BORNE TYPHOID FEVER IN CHAMBERLAIN, SOUTH DAKOTA

By W. W. Towne

(Director, Division of Sanitary Engineering State Board of Health, Pierre, S. D.)

1-12-41

A study of the United States Registration Area death records shows a phenomenal decrease in the typhoid fever death rate throughout the country during the past three decades. In 1900 the typhoid death rate was 35.8 per 100,000. This has been reduced during a thirty year period to 4.2 per 100,000 population, and in the northern states the death rate is even less. This decrease may be attributed almost entirely to a better understanding of the need for better sanitation and the application of proper water treatment practices and milk control measures. Today, public water supplies are not necessarily considered the major vehicle by which this disease is spread. Undoubtedly a large number of typhoid cases might be traced to a much closer contact with some carrier, than through the public water supply, and the disease can no longer be classified as one most common to congested areas.

Public protective measures have decreased the number of so called epidemics, and now the cases are well scattered as to location and time. This decrease in death rate, and the fact that the disease does appear as often in rural communities as in municipalities, has no doubt created a false sense of security among public health and water works officials, as well as the public in general. The fact remains, however, that water is still an excellent vehicle for the transportation and distribution of bacillus typhosus, and an infected public water supply will naturally expose a large number of people to the disease. As pointed out by Wolman and Gorman in "Water Borne Typhoid Fever Still a Menace,"[1] three of the largest typhoid epidemics on record occurred during the period 1920 to 1929. Because of this potential menace, public health and water works officials

[1] Wolman, Abel, Gorman, Arthur E. "Water Borne Typhoid Fever Still a Menace." The Waverly Press, Baltimore, Md.

cannot decrease their vigilance over the public water supplies or disastrous results are sure to follow.

THE CHAMBERLAIN EPIDEMIC

South Dakota has been comparatively free from typhoid fever for many years. The death rate per 100,000 for the past decade was 3.4, which is approximately one-half of the death rate for the United States Registration Area during the same period. For 1932, the death rate was the lowest recorded in the history of the state, namely; 1.4. However, during the last few days of 1932 an epidemic of typhoid fever developed at Chamberlain, South Dakota, which will raise the 1933 death rate to the highest point in many years. This epidemic was the most serious outbreak of typhoid in the history of the state, with a total of 282 cases, resulting in 29 deaths.

On December 29, 1932 the writer received a request to investigate the public water supply of that city. This investigation was made on December 30 and brought to light the following findings: Raw Missouri River water was being pumped directly into the distribution system, after receiving chlorination. The amount of chlorine used was not sufficient to maintain a residual after a very short period of contact. The milk supply for the city was derived almost exclusively from two dairies, one of which pasteurized all milk sold. A Parochial Indian School, having a population of approximately 75 people located just outside of the city limits, was discharging raw sewage into the river about three-fourths of a mile up stream from the city water intake and on the same side of the stream. Twelve cases of typhoid fever were known to exist in Chamberlain on this day. Many other people were suspected of being infected, but as yet the diagnosis had not been confirmed by laboratory tests.

In view of the above conditions, the water supply was suspected as the source of infection. If such were true it could be anticipated that this epidemic might reach rather wide spread proportions, and for this reason only a hasty preliminary investigation was made on this day, but immediate steps were taken to start a more complete investigation and to institute control measures which might be necessary should the number of cases increase materially. Only the necessary precautionary measures were taken to insure the safety of the water supply. The chlorine dosage was increased sufficiently to maintain a residual at the pumping plant. Orders were issued to boil all water used for domestic purposes. It was suggested to the

City Council that immediate steps be taken to immunize all people desiring this protection. Samples of water were collected at various points throughout the city and taken to the laboratory for analysis.

Upon the arrival at the laboratory the writer's fears were further confirmed. Out of 18 blood specimens submitted for diagnosis, 15 of this number gave the positive Widal reaction. Therefore, the Division of Epidemiology and the Division of Sanitary Engineering immediately set up temporary headquarters at Chamberlain, and the State Health Laboratory set up a temporary field laboratory to carry on tests in connection with the epidemic.

By January 3, the total number of cases confirmed by laboratory diagnosis was in excess of 100, thereby indicating that the total number of cases could be expected to reach a very high figure. Due to the rapid increase of cases reported during the first week of the epidemic, the services of the State Board of Health members were devoted almost entirely to the organization of relief measures and the installation of the necessary protection against every possible source of infection.

The control measures adopted by the State Board of Health at Chamberlain consisted of isolation of the sick with disinfection of all body discharges, vaccination of all people desiring this protection, regulatory measures regarding release of patients, chlorination and boiling of water, pasteurization of milk and the control of its distribution, and close checking and control of all food handlers.

The water used for domestic purposes in the city of Chamberlain was obtained from the public water supply system, private cistern water, and a bottled water known as Rocky Mountain Table Water.

Water supply

The source of supply for the city is the Missouri River, the raw water intake being located approximately 150 feet from the east bank of the stream. From this point water flows by gravity into a pump suction well from where it may be pumped either to a sedimentation tank, having a capacity of approximately 350,000 gallons, or directly into the distribution system. The point of chlorine application was in the pump suction well. The above mentioned settling basin is a concrete structure covered with a corrugated sheet metal roof. No heating facilities were available. Therefore, it had been customary to discontinue the use of this treatment unit during intense freezing weather. This was the condition in which the writer

found the municipal water supply at the start of the epidemic. As previously stated, the chlorine application was immediately increased to maintain a residual at the pumping station. It was found, however, that it was very difficult to carry a residual any appreciable distance from the pumping plant. This fact of course could be expected, due to the large amount of turbidity in the water and the accumulated deposit in the distribution system.

Immediate steps were taken to provide better efficiency in treating the water. A heating system was installed at the settling basin, and other minor changes were made which would increase the efficiency of sedimentation, after which it was put into operation. Raw water was then pumped into this basin and settled water was delivered to the distribution system. The point of chlorine application was changed to the suction of the high service pumps and alum and lime were added as a coagulant to the raw water. Under this arrangement it was possible to deliver a fairly clear water to the city. It was still difficult, however, to carry a chlorine residual throughout the system. Therefore, the system was flushed at frequent intervals to remove the accumulated sediment. The 200,000 gallon covered standpipe was drained and cleaned. A solution of chloride of lime was placed in this standpipe, sufficient in amount to produce a rate of chlorine dosage of 20 p.p.m. when the tank was full. This highly chlorinated water was then drawn throughout the system. After flushing of the mains had cleaned out the distribution system to some extent, it was then possible to maintain a residual throughout.

Due to the variation in the organic content of water, even after sedimentation, it was necessary to maintain a chlorine dosage of 2.0 p.p.m. With this application, the residual chlorine content at a point approximately 3,000 feet from the pumping station remained quite constant at 0.8 p.p.m., and in the far ends of the system the residual dropped still lower. In view of these facts, it was not believed advisable to reduce further the rate of chlorine application.

Samples of water were collected throughout this epidemic at regular intervals. Only the presumptive test for bacillus coli was run on these samples. The result of these tests show only three samples containing gas forming organisms after December 30, no gas forming organisms being present after January 4.

The bottled water known as Rocky Mountain Table Water is derived from the Missouri River, the intake being about 400 feet down stream from the city intake. In addition to the bottled water,

ice cream, butter, and pop are also manufactured at this plant. The purification system at this plant was checked and found to be inadequate. Therefore, the distribution and sale of products from the establishment was curtailed until such a time that the water supply should be satisfactory.

Regarding the cistern waters used it is significant to note that many of the cisterns examined, from a bacteriological standpoint, did not show the presence of gas forming organisms. This may be accounted for by the absence of bird life at this season.

Milk supply

Although this epidemic did not have the appearance of being a milk borne epidemic, in order to preclude any possibility of the spread of the disease through this source, and to protect the milk supply certain precautionary measures were instituted. All stores were prohibited from selling milk, until such time as individual containers could be supplied by the dairies, which were destroyed after use. All distributors were prohibited from leaving or picking up milk bottles at a residence in which a case of typhoid fever resided. Milk handlers were closely watched to detect the possibility of their contracting the disease. Temporary regulations were also issued by the State Board of Health requiring the pasteurization of all milk and dairy products, the pasteurization plant to be equipped with a recording thermometer, and all bottles to be capped with a mechanical capper. The two larger dairies combined their raw milk, which was pasteurized at the plant of the Riverside Dairy. Pasteurization of all milk and cream sold in the city was started January 7. The creamery at the Chamberlain Water Company, while pasteurizing all cream before churning, was prohibited from manufacturing butter until such a time that their water supply was of unquestionable quality.

Following the recommendations of the State Board of Health, the City Council adopted a milk ordinance requiring, among other things, pasteurization of dairy products, which became effective as soon as legal procedure would permit.

Other control measures

In addition to the above control measures, approximately 6,000 people were immunized for typhoid fever in Chamberlain and surrounding territory. The vaccine for these immunizations was furnished free of charge by the State Board of Health.

Isolation of all persons having the disease was required until permission for release was granted by the State Board of Health. The disinfection of all body discharges from infected patients was also required until release from isolation was granted. In order to insure compliance with this requirement the city furnished and delivered the disinfectant solution. This consisted of a chlorine solution having an available chlorine content of 15,000 p.p.m. Equal parts of this solution and the body discharges were thoroughly mixed and allowed to stand for two hours before final disposal. At those residences having outhouses, in addition to disinfecting the excreta with chlorine, the city furnished hydrated lime which was sprinkled over the contents in the pit at regular intervals. The excreta disposal was closely watched by a special sanitary officer, who reported very few violations of the instructions as prescribed.

Sewerage facilities

At the time of this epidemic the city of Chamberlain had no municipally owned sewer system. A considerable portion of the town, however, was served by eight separate privately owned sewer systems. Most of these sewers had their point of discharge some distance from the edge of the river, flowing in an open ditch from this point to the river. In view of this undesirable condition the State Board of Health recommended that the city construct an intercepting sewer which would collect the sewage flow from these various private sewers and carry the combined flow to a single outlet in the river. This work was carried on as an unemployment relief project, the city purchasing the material and the R. F. C. furnishing the labor.

POSSIBLE CAUSES OF EPIDEMIC

After the organization of control and relief measures was completed, it was then possible to collect and compile data which we hoped would reveal the source of infection, and the method of its spread. Case histories of each individual having the disease were obtained. In addition to this a complete census of the town was made. In this census, information regarding the source of water supply used for domestic purposes, the method of sewage disposal, the source of milk supply, and other pertinent data were obtained. The result of this census gave a total population at the time of this epidemic of 1,530 people.

The typhoid cases by sex and age groups are shown in table 1.

A study of this table will show a total of 282 cases of typhoid fever, 247 of which were residents of Chamberlain. Of the total number, there was a total of 29 deaths, 19 of which were Chamberlain residents. 247 cases occurring in the city of Chamberlain, with a population of 1,530, gives a case rate per hundred population of 16.1, or, in other words, approximately one out of each six persons contracted the disease.

TABLE 1

Typhoid cases classified by sex and age

AGE GROUP	TOTAL IN EPIDEMIC				CHAMBERLAIN CITY RESIDENTS			
	Cases		Deaths		Cases		Deaths	
	M	F	M	F	M	F	M	F
Under 1	0	0			0	0		
1– 5	19	9	2		18	7	2	
6–10	24	34		1	23	33		1
11–15	26	28	2	1	23	33		1
16–20	15	22	4	1	11	22	1	1
21–25	16	17	5	1	9	17	3	1
26–30	11	10	2		8	9	1	
31–35	7	8	1		7	6	1	
36–40	4	5	1	1	4	4	1	
41–45	3	5		1	2	5		1
46–50	4	4	1		2	2		
51–55	3	1		1	3	1		1
56–60	1	1	1		0	1		
61–65	0	3	1	1	0	3	1	1
66–70	0	1			0	1		
71–75	1	0	1		1	0	1	
76 and over	0	0			0	0		
Total	134	148	21	8	111	136	12	7

A study of the compiled data derived from the case histories and city census may be summarized as follows. No single milk supply was common to those infected. Cases were recorded reporting the use of no milk whatever, other cases used only condensed milk. In view of this information, it does not appear probable that this epidemic was milk borne. Another possible source of infection might have been the company manufacturing ice cream, butter, pop, and bottled water. These products received quite wide distribution within a radius of a hundred miles, and no cases were reported at

this time which did not have a closer contact with the city. Therefore, it seems likely that this possible source of infection may be discarded. The distribution of cases throughout the city was not confined to any one locality or section. Therefore, the source evidently was one which was common to all ages and classes of people. This fact, together with the intensity of the outbreak, eliminates more or less the possibility of there being any connection between foodstuffs or food handlers. The only remaining possible source appears to be the public water supply.

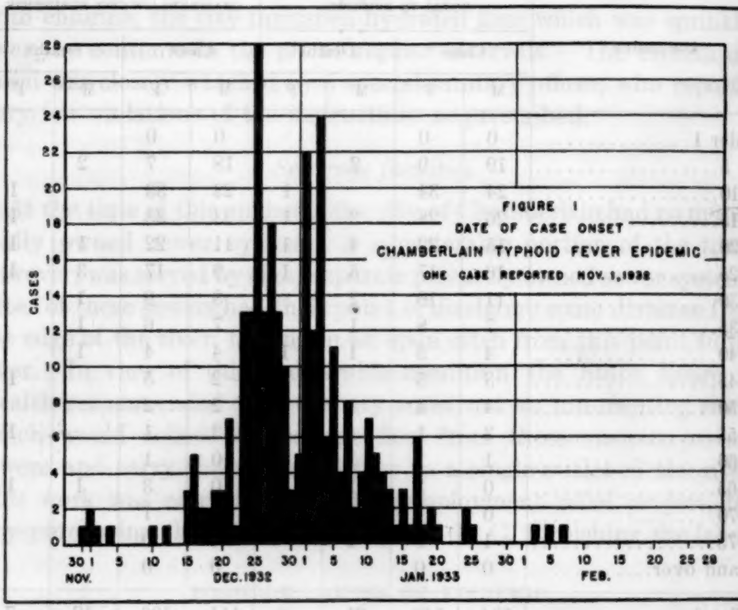

FIG. 1

A study of the compiled data brings to light the following information regarding the water supply. The number of cases contracting the disease and the date of case onset are shown in figure 1. A study of the operation records of the city water department shows that on December 9 the use of the sedimentation basin was discontinued, due to excessive freezing. A study of figure 1 shows that a few cases of typhoid fever occurred the earlier part of December. It was not until December 15, however, that the occurrence of cases showed a material increase. Assuming that the source of infection

was waterborne it is also reasonable that the by-passing of the sedimentation basin would decrease the efficiency of treatment and increase the infection in the water within the distribution system. Assuming that the major source of infection first entered the distribution system on December 9, the incubation period for those cases occurring December 15 would be six to seven days. The fact that a few cases occurred previous to this time can be accounted for by the fact, that even with the sedimentation basin in operation, the treatment was not sufficient to eliminate all contamination, but no doubt did decrease the infection materially. A study of the case histories also shows that every case among the city residents reported the use of city water for drinking purposes. Of all the outside cases, practically everyone reported frequent visits to the city, many reporting the use of city water for drinking.

In addition, a road construction crew working eight miles north of the city had been using well water until December 10, after which they obtained their water supply from the city of Chamberlain. Four men in this group developed typhoid fever on December 20, 24, 27, and January 8, respectively.

Typhoid also occurred in two families outside of the city who had recently filled their cisterns with city water.

The above census also disclosed the fact that 52 homes in the city of Chamberlain reported the use of cistern water exclusively for drinking purposes. Of this number only three homes had any typhoid fever. In two homes the male resident, business men in town, contracted the disease. In the other home two cases developed, one a teacher, and the other a student at the city school. All these cases reported using city water for drinking during the course of the day. Contact with other possible sources of infection were not particularly restricted.

Further perusal of figure 1 will disclose the fact that the number of people contracting the disease dropped materially about January 8. We previously stated only three samples of water showed contamination after December 30, no gas forming organisms being present after January 4. Vaccination was not started until January 3. Therefore, it cannot be reasonably expected that vaccination was responsible for the decrease in the number of cases at this early date. The most logical assumption appears to be that the source of infection had been eliminated at an earlier date. Inasmuch as all milk and dairy products were not pasteurized until January 7, this procedure also

could not have been responsible for this decrease in the number of cases at this time. Taking the above conditions into consideration, it appears that the most logical source was the public water supply.

In trying to determine the original source of this infection, the Indian School, previously mentioned, was immediately suspected as having one or more carriers. All students and employees were checked for Widals, resulting in 8 per cent positive reactions. There had been no cases of typhoid fever in the school at any time, nor were there any cases present during this epidemic. Stool specimens were collected and examined in the Laboratory from those persons giving the positive Widal reactions. No definite reactive typhoid bacilli, however, could be obtained. Regardless of this fact it is significant to note that, although this institution used Missouri River water after plain sedimentation, no cases of typhoid fever developed. It is possible of course that plain sedimentation might remove a considerable amount of infection, but it is improbable that a water so highly infected as to produce such an epidemic as at Chamberlain could be entirely freed of all infection by plain sedimentation. An important fact in this consideration is that the water intake for this institution is up stream from their own sewer outlet. Therefore, assuming that this epidemic was water borne it seems probable that the original source of infection no doubt originated at this institution.

GENERAL

Chamberlain is not the only municipality in South Dakota lacking proper protection from possible contamination. Undoubtedly some public water supplies of other states may also be included in this same classification. It is a well known fact that some 2 to 5 per cent of those people having had typhoid fever become carriers of the disease. Although all patients in connection with this epidemic were released upon obtaining two consecutive negative stool specimens, taken one week apart, it is to be expected that there have been some typhoid carriers produced due to this epidemic. Funds and personnel of the State Board of Health do not permit the necessary follow up work to determine which people may be carriers. Therefore, each person having had typhoid fever must, to a certain extent, be under suspicion. For this reason, it behooves water works and public health officials to take extra precautions necessary to protect the public water supplies from even a remote possibility of contamination.

This epidemic proves conclusively that the period is not yet reached

when typhoid fever may no longer be classified as a water borne disease. Any water supply, subject to intermittent contamination, will no doubt sooner or later be responsible for a similar calamity.

This paper would not be complete without acknowledging the coöperation given to the State Board of Health by the many private individuals and public health agencies. The citizens coöperated one hundred per cent in doing everything within their power to control further spread of the disease. Without this coöperation the situation would have been much worse than it was. The city officials also took the necessary steps immediately to improve their water supply.

Mr. W. F. Cochrane, who is now State Engineer for the Public Works Advisory Board of South Dakota, was employed by the city about the first of February to design a modern water treatment plant. The proposed design contemplates using the present sedimentation basin for plain sedimentation. From here the water will pass to a mixing basin where coagulating chemicals will be added, thence through a coagulating basin having a retention period of four hours at the designed rate of filtration, then through rapid sand filters of the gravity type into a clear well. From here the water will be pumped into the distribution system after receiving chlorination. It is proposed that this construction will be carried to completion under the provisions of the public works program. Contracts were let for this construction on October 2, contingent on government approval of the project.

Of all municipalities applying for federal aid under the public works program in South Dakota, Chamberlain surely should be given first consideration.

In those states in which public health work is in the very early stages of development, such as South Dakota, the layman cannot be expected to appreciate the necessity for all of these protective measures. This condition can only be changed by an educational program by state health authorities. Such work is being retarded at present by the universal tendency to decrease appropriations for health departments. Experiences similar to the one described in this paper, of course, bring the necessity of adequate sanitation once more forcibly before the public. We sincerely hope, however, that similar occurrences may not be necessary to awaken the public to the necessity of providing adequate sanitation, and that this paper

will help to demonstrate the false economy of neglecting public health control measures.

A more detailed report of this epidemic has been prepared by the State Board of Health as a special bulletin which will be gladly furnished to anyone requesting it.

(*Presented before the Minnesota Section meeting, October 20, 1933.*)

WHY VALVES? (to measure, of course)

By Edgar K. Wilson

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The subject of this paper was suggested to the writer during a conversation with some of the engineers of the National Board of Fire Underwriters, when the subject of the condition of valves was under discussion. The answer to the question "Why Valves?" is so obvious as to seem almost ridiculous to a water works man; and the resulting paper may be listened to with equanimity by every water works superintendent whose plant is in such condition that every valve in the system can be quickly located from complete records, is clear of débris so that it can receive the operating key without delay, is not in any way defective so that it can be operated promptly without using undue force, and can then be depended on to hold water without leaking when it is closed. To all such superintendents we can only offer our heartiest congratulations and hope that such ideal conditions will continue. To others this paper will contain nothing new, nothing with which we are not all thoroughly familiar; and its only purpose is to bring out a few of the common defects in a valve system which tend to decrease the value of the valves which have been inserted in the mains or which may even prove an actual detriment to the proper operation of the system. After a short discussion of some of these defects, a few "horrible examples" taken from actual records during Pitometer water waste surveys will be presented, which will show that poor valve conditions are not confined to the small plants or to those of greater size, but may be found in municipal and private plants of all sizes and in all parts of the country. As is probably known, during such Pitometer surveys from 75 to 90 percent of the valves in a water works distribution system are operated; and notes made of the number of turns, the direction of closing, the condition, etc., so that this feature of the report may be of the greatest value to the plant manager who desires the highest efficiency for his plant.

In this paper the valves to be discussed will be only ordinary valves used in the distribution system of water works, which are called in

various cities valves, gates, gate-valves, stops, etc.; and it will be well at the beginning to define their function.

FUNCTION OF VALVES

A valve is a mechanism inserted in the water main to control the flow of water.

When a water main is laid valves are inserted more or less regularly at points where it may be desirable to shut off for repairs or for other purposes. Sometimes the locations chosen are not the best which could be picked for the purpose, but at all events the valves are set and paid for because it is expected that they will do certain things when necessary. If they will not accomplish these objects their cost is wasted.

Referring to the definition given above, the first point is that a valve is a mechanism. It consists of gates which may be raised or lowered, a screw extending through a stuffing box so that it may be turned from the outside, a nut or wedge by which the screw moves the gates. This may not be as delicate a mechanism as the works of a watch, but it still is a mechanism and as such it must have a certain amount of care and attention.

To complete the arrangement some method of access from the street surface must be provided, a vault, manhole, or street box.

A valve in the system may be compared in some respects to a fire door held in its open position. If you have such a door in a building there is usually a sign to the effect "Keep This Door Clear," and it is not customary to pile tar, cement, sand or rubbish against the door in such a manner as to prevent its closing when necessary. Yet this is what very often happens in the case of water works valves. The top of the valve box may be covered with concrete or asphalt paving, gravel, etc., or the box itself may be partly or completely filled with these subtances or other rubbish which will prevent the easy and rapid operation of the valve in time of need. If such materials were piled against the fire door the insurance and fire department inspectors would see that they were cleared away; but the valve may have no relief of this kind until it is needed, possible to shut off a leak capable of doing many hundred dollars worth of damage, while the valve is being located, cleared and closed. The mechanism is useless unless it is accessible for the purpose intended.

Again the mechanism will be useless if it cannot be operated when it is reached. As mentioned above the screw operates through a

stuffing box. The packing in the gland will dry out in time and the valve may leak when it is wide open. To stop such a leak without repacking the valve the operators sometimes jam the screw as hard as possible in the open position. This will often stop the leak, but if the stem is left in this state for long it usually becomes stuck so that it is almost impossible to operate the valve. Then if there are both left and right hand valves in the system and the records are poor, it is very likely that a broken stem will result the next time the valve is operated.

If a valve works hard it is very easy, unless care is used, to bend the stem, which makes it even more difficult to operate, and may render it impossible to completely open or close the valve. The valve is then worse than useless, because under operating conditions, the flow of water is obstructed, sometimes very materially, and in case of need it cannot be closed and may be thought closed when in reality it is partly open.

In the course of operations it is inevitable that some valves will be broken, especially where maintenance has not been considered. One of the best ways to prevent the repairs of broken valves is to give the foreman a good dressing down when he reports such an accident. After two or three experiences of this kind, reports of broken stems will dwindle, perhaps to the vanishing point. Then when a valve is badly needed it may be found impossible to operate and nobody will know when it was broken. A tolerant spirit shown by the official in charge will encourage frankness in this matter and repairs may then be made immediately. Of course, too many broken valves may indicate carelessness which should be checked as soon as possible. Most superintendents and many foremen know how to operate valves properly, but how many superintendents know whether their foremen and valvemen are following the best methods? It is not enough that a valve be turned as far as it can be forced. The number of turns needed to close each valve should be known; and if the required number cannot be obtained without forcing, the valve should be backed off a few times to allow the corrosion and other deposits to wash out of the seat. This is good practice even when the valve works easily, and is required in some cities. Such methods will help to keep the number of broken stems at a minimum.

A point often neglected in the care of valves is the oiling of the gears of valves so equipped. Very little time is needed to oil such gears, but if this is neglected, corrosion may completely prevent the

operation of the valves without considerable delay in cleaning out the rust.

MANHOLES AND STREET BOXES

The question as to the use of manholes or street boxes for the protection of the valves is one which must be answered by each plant for itself. Some systems have manholes for every valve, while others use them in pavements. Still others place a manhole over every new valve or over all valves where new pavement is to be laid. The principal value of the manhole is, of course, to provide access to the valve especially for repacking the gland or replacing a stem. Where finances allow this method of protection is undoubtedly best, at least under pavements; but its expense is high when the probabilities of needing to dig up a valve for either of these repairs are considered. To insure long life for the packing some cities repack all new valves before they are installed, with packing material which they have found to be best suited for the conditions of their own particular system. It is probable that the cost of occasional digging up even of new pavement for valve repairs will not entirely justify the cost of the manhole over the street box; but other things enter into the problem, such as interference with traffic in the busy sections of a city, which may more than justify the extra expense.

ADEQUATE LOCATION RECORDS

The other point of the definition is that a valve is to control the flow of water. In the first place how can water be controlled by a valve if it is not known how the mains are connected? How many times we have seen beautifully drawn maps showing in great detail valves and connections at intersections, which, when taken into the field, have shown that they were made from insufficient or incorrect data. Sometimes this is due to carelessness, but perhaps more often to inaccurate memories of men in the department who have supplied the information. Where the least doubt exists connections should be checked up from office records if these are available, by use of the wireless pipe locator, and by actual tests in the field. In extreme cases where other methods fail it may be necessary to dig up the intersection, in which case a closed valve may be found of which there is no record, or the connection can be made if none exists.

Again, how can water be controlled if the locations of the valves are not known? In a large city a few years ago a bad break in a main

occurred and all available men of the department arrived on the scene armed with gate keys, and because the proper gates could not readily be located to stop the leak, they immediately began to shut every gate they could find. The effort was successful—the leak was shut out after awhile—but there has always been a question in the writer's mind as to how many of the extra gates which were closed in the excitement were opened after the emergency was over. No notes were taken at the time of closing and the opening depended on the memory of the men, most of whom were laborers with little or no direction by foremen. This incident brings up the question of making records of valve operations. We believe that records should be made every time a valve is operated, giving the time, date and reason and clearly stating if the valve was left open or closed. If valves are to be operated as above by anybody who can turn a key and without supervision by a foreman, such records are impossible. With proper organization it would seem perfectly feasible, and it is done in some systems, to have each operation properly supervised and recorded; so that after a shut-down is cleared, it may be known positively that all gates are in their normal positions.

RIGHT AND LEFT HAND GATES

Many cities have both right and left hand gates in their distribution systems, using the term left hand to designate those which are operated in a direction opposite to the majority. We have known instances of this being caused by removal of a gear from an upright geared gate, but such cases are rare and can usually be recognized at a glance. Perhaps a system with only a few left hand gates is apt to have more trouble than the system where the two are about evenly divided; since in the latter case it is well understood that all valves are not standard, and precautions are taken to look up records, when available, before operating a valve where there is any doubt. In both cases, the different directions of operation introduce an element of doubt which interferes with the prompt and efficient operation of valves in time of emergency.

It is very desirable that these left hand valves be marked in some way so that anyone having occasion to operate them will know at a glance that they are not standard. A simple cup shaped iron casting with a loop in the top to get hold of may be placed over the operating nut or a distinctive cover placed on the box. Similar markers or reminders may be used to indicate valves which are kept closed for

purposes of operation such as pressure section boundaries. The devices should be enough different so that a boundary valve will not be mistaken for a left hand valve.

The answer to these three points, of course, is accurate and full records, and the insistence that all men entrusted with the operation of valves shall refer to the records where the least doubt arises as to the location or direction of operation of any particular valve. Where new work is laid, whether by contract or otherwise, it should be visited by an inspector at frequent enough intervals so that it will be definitely known what materials, valves, specials, etc., are brought onto the ground and where each item is installed. If the gathering of such information is left until the job is finished, some pieces may be covered and it will be too late to get the data properly.

EXAMPLES OF DIFFICULTIES

To show that there may be a reason for this paper, a few excerpts as to valve conditions will be made from reports of the Pitometer Company on water waste surveys. These will be taken at random from several hundred such reports, no attempt being made to select the worst or best cases.

City number 1 (Population 61,000):
10 found broken closed (includes 3–12″; 1–16″)
8 found broken open
10 found closed or only partly open (1–24″; 3–12″)
26 various defects so that valve could not be operated.

Total.... 54 valves defective, including some of the most important feeders.
3 left hand

City number 2 (Population 15,000):
5 found closed
11 covered over
8 various
2 could not be located

Total.... 26 including 1–10″ valve (largest size in system)

City number 3 (Population 109,000):
72 paved over (2 had two distinct pavements over it and one had 18″ cover)
16 found closed or broken

20 boxes filled
14 various

Total.... 122 valves defective
6 left hand

City number 4 (Population 65,000):
16 found closed
7 found broken
13 buried
23 boxes filled
2 various
6 could not be located

Total.... 67 valves defective
21 left hand

City number 5 (Population 69,000):
12 found broken
8 found closed
8 covered over
12 boxes filled or shifted
7 would not hold water
29 various

Total.... 76 valves defective
In addition there were many left hand valves which were the subject of a special report to the officials.

City number 6 (Population 5,300):
2 found broken closed
3 found broken open
2 found closed
1 would not hold

Total.... 8 valves defective
11 left hand

City number 7 (Population 33,000):
18 found closed (includes 18″)
2 could not be operated (includes 20″ at pumping station)
8 found broken closed (includes 16″ and 14″)
1 found broken open
3 boxes covered (1–3′ below grade; 1–2′ below)
1 box filled
2 would not hold
29 various

Total.... 64 valves defective

City number 8 (Population 6,000):
1 found closed
2 left hand

City number 9 (Population 26,000):
75 percent of valves paved over or buried, some so deeply that they could not be located by a dip needle. Location measurements were often useless because of removal of objects from which measurements had been made.
Only 2 valves defective mechanically.

City number 10 (Population 3,800):
10 found broken open
2 found broken closed
11 found closed
5 boxes shifted
4 buried or paved over
5 various

Total.... 37 valves defective
2 left hand.
In this case the defective valves totaled 27 percent of the total number operated.

These examples will indicate that the misuse and neglect of valves are not confined to cities in any one section of the country or to any particular population range. The best showing in the above list is made by a small town, but another smaller town gives the worst record. Reports might be picked out of larger communities which show enviable conditions, but the above list of ten gives a fairly good cross section of the cities where Pitometer surveys have been made.

Why valves? To control the flow of water; but if the valves, inserted in the lines at considerable expense, cannot for any reason be used to control the flow of water, they are useless and in some cases may be a positive menace especially to the fire protection of a community.

The remedy for these conditions is to make careful records of the locations, keep the covers free from paving or other overlying matter, keep the boxes clear of débris, test the valves by complete closing and opening operations at intervals of not over a year to see that they are in working order, make repairs promptly, and—perhaps most important of all—train your valve operators to handle the valves as if they were mechanisms instead of junk.

Why valves? To control the flow of water; and when the valves in a system are kept in such condition that they will control the flow of water, then the superintendent will have one less worry when the fire alarm rings or a break in the mains is reported.

(Presented before the New York Section meeting, August 24, 1933.)

TASTES AND ODORS IN THE DELAWARE RIVER

By J. Wendell Burger and Stanley Thomas

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For years prior to 1933, the Lehigh Water Company, which supplies the city of Easton, Pennsylvania, received complaints regarding a distasteful condition of the water. These investigations were carried on in an attempt to discover the nature of such taste and odor troubles, and the possibility of rectification.

With the exception of the taste of the water, the Delaware River at Easton is a fine natural water supply. This is testified by the fact that prior to March, 1933,[1] a water fit for consumption was supplied to Easton with no other treatment than chloramine. The raw water is soft, alkalinity 14 p.p.m.; total hardness 30–50 p.p.m.; total solids 50–60 p.p.m. The turbidity is normally under 5 p.p.m., and while it rises with rains and flood waters, a week's storage capacity is sufficient to await subsidence. Color rarely reaches a maximum of 10 p.p.m. As the river flows through sparsely inhabited country, there is no excessive fecal pollution; the B. coli index averages 10, ranging from an occasional high of 1000, to as low as 1. There is no evidence of industrial polution.

At present, after a year's survey, only one taste is to be found. This taste is constantly present, being absent only twice (October 19, 1932, and January 10, 1933) after prolonged rains. Realizing descriptions of taste are at the best unsatisfactory, the nearest approach for this taste is to call it earthy-musty. The taste is more pronounced than the odor. Heating does not increase the odor to any great extent.

This taste is by no means peculiar to the Delaware River. Seven out of nine of its larger tributaries have it. Moreover, of 25 rivers, creeks, and brooks tasted between Allentown and Philadelphia, 18 had this taste decidedly, 7 were faint or tasteless. It is a taste common to streams in eastern Pennsylvania.

[1] At which date a modern filtration system was put into operation.

DISTRIBUTION OF TASTE

As indicated by prevalence of the taste in streams of this area, no localization of the taste to one source was possible. There is a gradual increase of the taste as the river flows southward from Hancock, N.Y., where it is formed by the union of two branches, to Easton, Pa. No tributary stream has a stronger taste than the Delaware; nor is the taste in the Delaware below any tributary greater than would be expected after dilution.

This disposes of such sources as the great Wallenpaupack power reservoir that ultimately empties into the Delaware via the Lackawaxen River. All streams were tasted themselves, as well as the Delaware above and below their point of entry. The significant fact of this survey is the gradual increase in intensity downstream.

POSSIBLE CAUSES

A number of possibilities are present that might account for the taste: (1) extensive growths of the spermatophytes Elodea and Vallasneria; (2) algae of all sorts; (3) miscellaneous protozoa, fungi and water animals, etc.; (4) bacteria; (5) organic matter—(a) fecal, (b) non-fecal, largely decaying plants.

(1) The spermatophytes Elodea and Vallasneria occur with profuse growth, particularly Elodea. This plant occurs in heavy beds in the river floor. It appears early in the spring, and persists late into the fall. During the winter, the dead stems are slowly broken off, and disintegrate.

These growths and various algae growths, notably Cladophora and Spirogyra, are responsible through their photosynthetic activities for a marked fluctuation of pH throughout a summer day—a range that might be from 6.9 in the morning to 8.9 in mid-afternoon. This phenomenon has been noted by others,[2] and in this case confirmed in the laboratory. Moreover, after cessation of growth in October, the pH variation was not more than 0.1–0.2.

To determine what effect Elodea might have on taste, carefully washed plants were put in an aquarium fed slowly by a stream of tasteless spring water. Daily testing for 7 days was negative. The tap was turned off for two weeks during which time Protococcus, Melosira, and Navicula became profuse without effect. A water and

[2] Buswell, A.M.: Chemistry of Water and Sewage Treatment, p. 155, Chemical Catalogue Co., 1928.

alcoholic distillate of Elodea yielded a highly offensive solution which in no way approximated the taste in question. Vallasneria is not as abundant as Elodea, and offers nothing to incite suspicion. Both these plants are rather conclusively eliminated by their absence during the winter months. So it is concluded that these Spermatophytes are not the causative agents.

(2) Algae. The discussion at this place will be limited to those aromatic oils released by various algae. These are the substances usually responsible for algae taste troubles, having specific qualities for specific genera. Since the Delaware River taste is a constant one, it would be necessary to establish the omnipresence of one or several organisms. Moreover, any such organism must be shown in sufficient numbers.

The fact that the taste is constant throughout the year, eliminated all organisms that are not continuously present. A minimum of one microörganic count per week was made for the year 1932–33, and although over 50 genera of algae and allied protozoan forms were found, none were constant enough in their presence. For example, the tons of Cladophora and Spirogyra which line the river existed only from July to October. Further, there were no qualitative fluctuations of taste that can be linked to periodic existence of certain forms. And again, the highest number of free forms per cubic centimeter, exclusive of diatoms, was 52 distributed through 6 genera.

Due to greater constancy of appearance, the diatoms must be considered. This population presents a less fluctuating picture than the other algae. An average per cubic centimeter of any genera is well under 10, and none of them, even Navicula and Synedra, was found every time. Of course, these forms are swept into the running water from more sheltered havens such as vegetation, river floor, etc. Examination of such spots indicated that growth in such places was not great enough to account for a taste in view of the dilution caused by the river. Moreover, rainy periods where agitation of the floor occurred did not increase the diatom count to any marked degree, nor was there any correlated rise in taste.

Again, tasteless water from one of its tributaries (Brodhead Creek) had more Synedra per cubic centimeter than the Delaware on that date. Also the taste was found in a laboratory tank (discussed below) where only a few Synedra were present.

Other diatoms occurred in greater numbers than mentioned, but less constantly. Asterionella, a persistent winter form, was absent

at the time of maximum taste, viz., August. Cocconeis was abundant in the summer. It is interesting to note that Cocconeis is linked with Elodea in growth. Elodea from other streams always had this organism present, while on the floor of the stream or other vegetation, Cocconeis was rather scarce.

From these evidences there is little possibility of the "natural" oils of algae being involved.

(3) Miscellaneous items as fungi and protozoans give no indications of trouble. Protozoans were never more than several per cubic centimeter, never of a constant species, and were about equally distributed through the Sarcodina, Mastigophora, and Infusoria. Likewise there was little fungi growth at any time.

(4) There then arises the question of odoriferous substances, peculiar to bacteria—as various oils are peculiar to the algae. Bacterial isolation was carried on throughout the period of observation, in the main upon nutrient agar; although other media were occasionally used. During this time, the only odoriferous bacteria were the Actinomyces. The actinomyceal odor, however, is more moldy, and while somewhat similar can be readily separated from the river odor. Moreover, these Actinomyces were rare, and although a single colony can emit considerable odor, the difference in odor and the paucity of the organisms seems sufficient to discount them as a cause of the taste.

(5) By elimination one is led to non-living organic matter. It is realized that the evidence offered so far has been largely negative; and hence more positive data is required. The organic matter to be considered is (a) fecal, (b) decomposition of life in the river, tributaries, and water sheds.

This laboratory made sanitary surveys of the river and tributaries from Hancock, N. Y., to Easton, Pa. The B. coli indices fluctuated at various points on the river, and nowhere was there heavy fecal contamination. This is in accord with the Pennsylvania State Survey made under Christian L. Siebert,[3] that demonstrated "the waters of the Delaware River from the Pennsylvania-New York line near Hancock, N. Y. to Easton, Pa., and Pennsylvania tributaries thereto related are relatively clean except for local pollution." The low nitrogen results[4] clearly indicate this:

[3] Siebert, C. L.: Delaware River Survey, 1929. Pennsylvania Sanitary Water Board.

[4] Average of three years from analyses of Dr. J. H. Wilson, Professor of Chemistry, Lafayette College, Easton, Pa.

	p.p.m.
Nitrate (NO_2)	0.015
Nitrate (NO_3)	0.64
Ammonia (NH_3)	0.32
Albuminoid (NH_3)	0.16

That the taste was due to organic decomposing matter was early suspected, and the negative evidence of contamination points that way.

Moreover, positive evidence is at hand. The Elodea distillate, originally in no way like the river taste, was allowed to stand in a water sample bottle. After seven months, an intensified river taste was found. Ulothrix, when allowed to decompose, gave the taste. In a laboratory tank that had no fresh water for several months, and contained much decomposing algae, the taste was found. These algae were Chlamydomonas, Mougeotia, Scenedesmus, Selenastrum in large numbers, and very scantily even in propitious places, Cosmarium, Navicula, and Synedra.

All these can be eliminated. We have demonstrated elsewhere[5] that Chlamydomonas in an actively growing state produces no taste. Yet this organism, if caught in a tap that is not used for a day or so, will cause the first glass of water drawn to have the river taste intensified. Brown blobs of this organism's palmellae are odiferous with the river taste, while fresh green blobs are not.

Mougeotia, when grown in relatively pure culture in another tank, produced no taste. Scenedesmus and Selenastrum have never been reported as taste causers. The almost complete absence of Synedra —Syndera pulchella—removes any lingering doubt over this organism. The paucity and lack of report as taste producers of Navicula and Cosmarium dispose of them.

Moreover, it was shown that none of the algae released the river taste immediately upon death. Chlamydomonas, Ulothrix, Mougeotia, Cladophora, Spirogyra were killed by gentle heating, with no river taste resulting.

Further the taste was extracted from the mud of the river banks—mud which contained no living algae. The taste substances were digested with NaOH and precipitated with HCl. The precipitate was highly potent with taste, while the supernatant fluid was tasteless after complete precipitation.

The result of Berkefeld filtration may be helpful. Here the taste

[5] This Journal, July, 1933, pages 991–999.

was diminished, but not reduced. Now, if it were due to oils or some produced substance, one would expect a uniform removal or retention, but with decomposing materials of all sizes, the result would be expected as found.

The taste is evidently caused by stable material. The NaOH digest held it for several weeks when discarded. Bottles of water also retain it, losing the taste only slowly. Moreover, it is not highly volatile, as heating does not increase very markedly one's perception of it.

No rule can be laid down as to seasonal intensity. In the main, maximum taste occurred in August, and minimum taste in October and through the early winter. The minimum taste occurred late in October after a period of heavy rain that scoured the river. There seems no correlation with rise of turbidity and taste intensity—in fact, the clearest water often has the most taste.

Taste is also connected with amount of living matter present in the river. During August enormous beds of Cladophora, Spirogyra, in which Hydrodictyon was caught, furnished abundant organic matter. In the fall these organisms were flooded out, while the taste dropped. However, during the winter the river bed was covered with a felt of Ulothrix which holds until spring, as well as dead stands of Elodea.

The question arises as to what bacteria are associated with taste production. The difficulties attending the production of the conditions of natural disintegration are realized. All our controlled experiments to this end were failures. These failures, as is realized now, may be in part explained by the insufficient time allowed to bacterial action.

Hence, the data are based on bacterial isolations made from various sources where the taste was found: i.e., the river; the laboratory tank containing the taste; and the Elodea distillate. It must also be borne in mind that the isolation on ordinary culture media does not give a picture of the total bacterial population; e.g., members of the Nitrobacteriaceae, and many higher bacteria and fungi are excluded. Further, certain symbiotic relationships are destroyed.

The only genera common to the three sources were Flavobacterium and Achromobacter, which seem scarcely sufficient to cause the taste. The similarity between the river and laboratory tank was found elsewhere in the laboratory tanks where no taste was to be noticed. Moreover, in the Elodea distillate, fungal growth was considerable at a period when the characteristic taste had not yet appeared. Thus there seems little ground to blame the fungi alone.

The process seems to be clearly a slow microörganic disintegration, produced by no specific microörganism, but rather by a group of species in which the saprogenic action of fungi may well have a part. The taste appears more or less as a stable end-product of such disintegrative activities.

CORRECTIVE MEASURES

The problem of taste removal is one that is not well fitted for laboratory experiment. Comparison of laboratory results with plant operation findings at Easton, while in broad outline were in agreement, yield such disparity of quantitative results as to be useless. This difficulty is well recognized in water works practice.

Use of alum floc alone is insufficient to remove the taste, with various amounts of alkalinity, with a clay nucleus, or with sodium aluminate. This fact was most markedly demonstrated when a filter schmutzdecke was prepared in 1 liter of water with about 0.5 liter of floc. Here despite the very marked heavy precipitation of the aluminum hydrate, the taste persisted.

Following the work of Farrell and Turner[6] on the use of anthracite coal as a filter medium with the hope that the adsorptive ability of carbon would take out the taste, coal filters were made. These were constructed in percolators of 4-inch inside diameter to a depth of 15 inches, flow was one-seventh foot per minute, considerably slower than the usual rapid sand filter flow, which easily compensated for the halving of filter depth. Consequently, if these failed to work, the normal filter will not. Filter runs were made with unflocced and flocced water, with and without a schmutzdecke on the filter. No taste removal was experienced.

The activated carbon, Nuchar, and prechlorination were then employed. The success of activated carbon was negligible with a dosage of 0.8–1.0 p.p.m. Prechlorination finally solved the problem (removing the taste entirely) with the treatment averaging about 2.9 p.p.m. for the three summer months.

Until August certain slight recurrences of the taste are not clear. These recurrences appeared at consumer's taps, even though water was uniformly tasteless at the filter plant clear well. It seems most probable that deposits in the pipes were taken up by the water, for all such

[6] Farrell, M. A. and Turner, H. G.: A Comparison, as Filtering Media, of Fine Anthracite and Sand. Water Works Eng., Dec. 2, 1931.

local disturbances were transitory. From August on, however, no such complaints have been received.

CONCLUSIONS

1. The earthy-musty taste of the Delaware River is a taste common to streams of eastern Pennsylvania. In the Delaware it is attributable to no one form, to no particular microörganism, but is a product of organic disintegration throughout the course of the river.

2. Plant correction of this taste trouble is satisfactorily accomplished by prechlorination treatment.

CITY LIABLE FOR TYPHOID FEVER CONTRACTED THROUGH PUBLIC WATER SUPPLY[1]

The plaintiff, Edwin J. Campbell, brought action to recover damages suffered as the result of drinking contaminated water furnished by the city of Helena, Montana, and from which he contracted typhoid fever.

His complaint alleges that the city owns, maintains, operates and controls a water supply and system in its corporate capacity from which it furnishes water for drinking and domestic purposes on a rental basis, and so furnished water to the place where this plaintiff resided during the period covered by the allegations. It is then alleged that, in the summer of 1929, through the negligence of the defendant, its officers, agents and employees, the water became contaminated and that for a period of at least four weeks prior to the time when plaintiff became infected, the defendant had knowledge that the water it was furnishing him was germ-laden and unfit for human consumption, yet negligently failed to remedy the situation or warn plaintiff not to drink the water; that he did drink of the water at his place of residence on the 13th day of September, 1929, and thereby contracted typhoid fever from which he was seriously ill and confined to a hospital for a period of three weeks, to his damage in the sum of $10,000.

The defendant moved to strike certain portions of the complaint, which motion was overruled, and then answered, admitting that it owned and operated the water system, but denying that it did so in its corporate capacity, and denying that it has control over the water supply. It further denied that it had any notice or knowledge that the water was contaminated prior to September 16, 1929. The answer set up two special defenses, the first being that the duty to determine the condition of the water was transferred by statute to the State Board of Health and its subordinates, the county and city health officers who had knowledge of the condition for some time

[1] No. 6975, State of Montana. In the Supreme Court, June Term, 1932. Edwin J. Campbell, Plaintiff and Appellant, vs. City of Helena, Defendant and Respondent. Submitted: June 14, 1932. Decided: July, 1932.

prior to September 13, but failed to notify the city, and, second, that the plaintiff was not entitled to maintain his action by reason of the fact that he had not given written notice of his injury to the city as required by law.

The plaintiff moved to strike the special defenses from the answer, which motion was denied, and then demurred to the answer; the demurrer was overruled and plaintiff given ten days in which to further plead; he refused to plead further and thereupon defendant moved for judgment on the pleadings on the ground that each special defense constituted a complete defense to the cause of action pleaded. This motion was sustained and judgment of dismissal entered. The plaintiff has appealed from the judgment.

Three questions are presented for determination. First: In operating a municipally-owned water supply and system, does the city act in its governmental capacity or a corporate capacity? Second: Do the laws creating a State Board of Health and subordinate county and city health departments take the control of water systems out of the hands of the city so as to relieve it of the duty of maintaining a pure supply of water? Third: Does the law require one injured in the manner plaintiff alleges he was injured to give notice to the city as a condition precedent to the maintenance of an action for damages?

1. A city is not required to furnish water to its inhabitants, but it may do so, and when it does purchase a water supply and construct a system for its distribution and by means thereof furnishes water to the inhabitants, it is clear that it acts, not in its governmental capacity, but in a private corporate capacity, and should be accorded the same privileges and be charged with the same duties as any private corporation performing the same service for the people. (Public Service Commission v. City of Helena, 52 Mont. 527, 159 Pac. 24.)

2. The defendant may be said to admit the correctness of the foregoing statement of the law, but it contends that in the protection of the public health the city acts in its governmental capacity, which governmental function is, by law, imposed upon the State Board of Health and its subordinates, the county and city health officers.

A careful reading of the statutory provisions respecting the powers and duties of the State Board of Health (secs. 2641–2657, Rev. Codes 1921), and of their subordinates, the county and city health officers (secs. 2444–2502, Id.), discloses that, for the protection of the public health, these officials are given "general oversight and care" of the *sources* of all water supplies for domestic use and of the installation

of water systems and sewer systems as affecting such supplies, and are commanded to consult with and advise the city authorities in such matters. It has supervisory control over the subordinate health officials and may promulgate rules and regulations, and the health officers are authorized to investigate, on complaint, alleged nuisances tending to pollute water supply *sources* and prohibit the continuance thereof.

This board has general supervision over the "interests and health of the citizens of the state" and may appoint local health officers if the local authorities fail to do so. The local health officer is authorized to make sanitary inspection whenever and wherever he has reason to suspect that anything exists that may be detrimental to the public health, and, under rules promulgated by the state board, he shall investigate "suspicion" of the existence of such a condition, and shall investigate premises on which cases of typhoid fever exist and take necessary steps to prevent spread of disease and prevent the use of water which may be a probable source of infection, and abate nuisances affecting water used for human consumption.

But all of the powers, duties and authority vested in these officers pertain with the same force when a water system is owned, controlled and operated by a private person or corporation as when it is municipally owned, controlled and operated.

If, then, the reposing of power in the health officers to protect the public health in the manner designated, relieves a city of liability for negligently and knowingly furnishing polluted water to its customers, all private enterprises performing a like service are likewise relieved. This cannot be. The city furnishes water to its inhabitants in its private corporate capacity and it stands exactly in the shoes of the old Helena Water Company from which it purchased the plant; its activity in supplying water for domestic purposes, for hire, carries with it the duty to exercise care, commensurate with the risk involved, to see that the water which it supplies is free from filth and germs which will affect the health of its customers, just as is a private operator of a water system.

To say that the city is required to supply an adequate amount of water, but is not concerned with the quality of that water because the quality has to do with the public health, would be a refinement of technical hair-splitting. To say that the health officers have been negligent is no defense to the charge that the city knowingly delivered polluted water to a customer; if the attempt was to hold the city

liable in a matter wherein it was *obeying* a mandate of the health officers, a different question would be presented.

Even where it is held that, as the statutes give to the health officers supervisory control, the city is not required to "watch over the quality of the water as affected by the natural sources of supply," the city "is bound to keep its sewers and streets in such condition that the waters will not be polluted." (Dansher v. City of Brooklyn, 4 N.Y. Supp. 312.)

In Griffith v. City of Butte, 72 Mont. 552, 234 Pac. 829, this court quoted from Denver v. Maurer, 47 Colo. 209, 106 Pac. 875, as follows: "When a city, acting in its private corporate character, by means of a sewer, created on its streets a condition that menaced the health and comfort of the community, no authorities need be cited to show that it was a private corporate duty to remove the condition from its streets. It follows, therefore, that the flushing of that sewer, though done to preserve health and comfort, was not done primarily in the performance of the governmental duty pertaining to the preservation of health, but was done in discharge of the general duty of caring for the streets." So here, the protection of the water supplied from pollution within the corporate limits and the correction of a condition brought about by negligent care of a sewer main, was but a part of the corporate duty of the city. (6 McQuillin on Municipal Corporations, 900.)

3. Does the allegation of the answer that plaintiff failed to give the notice required by section 5080, Revised Codes 1921, constitute an effective defense to the action?

Section 5080 declares a prerequisite or condition precedent to the right to maintain an action for damages in all cases to which the provisions thereof have application. (Tonn v. City of Helena, 42 Mont. 127, 111 Pac. 715, 36 L. R. A. (n.s.) 1136.) But are those provisions applicable here?

The provision requiring notice was first enacted as Section 1, Chapter 93, Laws of 1903, under the title "An Act relating to actions against cities and towns for damages to persons injured on streets and other public grounds by reason of the negligence of any city or town in Montana." This Act was carried forward, without change, but without its title, into the Codes of 1907, as section 3289 thereof, and later, without change, into the Codes of 1921.

It is asserted that because of the codification of 1921, the Act is divorced from its title and we cannot now look thereto for the purpose

of interpretation; however, this court found no difficulty in interpreting it with reference to its title in 1911, after the Codes of 1907 had been adopted and approved by the legislature. (Kelly v. City of Butte, 14 Mont. 115, 119 Pac. 171.) No change was thereafter made by the legislature and it must be presumed that that body was satisfied with the interpretation given the Act by this court.

The court may always look to the title of an Act to determine the intention of the legislature and the purpose of its enactment, and this is so regardless of the mere formal codification of the laws of the state at a subsequent date.

The title above quoted clearly indicates that the Act was intended to apply only to those actions arising out of neglect in the performance of governmental functions, the care of "streets and other public grounds," and to require notice only in case of injury "on" streets and public grounds. Clearly, under the title of the Act, the instant case does not come within its provisions.

Here, the allegation is that the plaintiff was injured by drinking polluted water, not in or on any public place, but in the place where he resided,—a private residence.

But we need not depend upon the title in order to determine that the legislature did not intend the Act to apply to such an action as this. Such a requirement as we have here is in derogation of a common right and should be strictly construed so far as the necessity for the notice is concerned. (East Chicago v. Gilbert, 59 Ind. App. 613, 108 N. E. 29, 109 N. E. 404; Tatton v. Detroit, 128 Mich. 650, 87 N. W. 894; Reed v Kansas City, 195 Mo. App. 457, 192 S. W. 1047; Ninon v. Syracuse, 172 N. Y. App. Div. 39, 158 N. Y. Supp. 470; Gausted v. Enderlin, 23 N. D. 526, 137 N. W. 613; Titus v. Montesano, 106 Wash. 608, 181 Pac. 43.)

Section 5080, supra, provides for notice before any city or town shall be liable for "any injury or loss alleged to have been received or suffered by reason of any defect in any bridge, street, road, sidewalk, culvert, park, public ground, ferry boat, or public works of any kind." The nature of the places mentioned indicates that the body of the Act was intended to apply only to those places kept by the municipality in the discharge of its governmental function, and, under the rule of *ejusdem generis,* and under the rule of strict construction above stated, the statute cannot be extended to include actions for injuries sustained by reason of negligence in discharging purely corporate duties.

The supreme court of Minnesota has held that the statutory notice is required under fact conditions identical with those here presented (Frash v. City of New Ulm, 130 Minn. 41, 153 N. W. 121), and it is said that the statutory requirement on which the court made its pronouncement is, in all essential particulars, identical with our section 5080. This is not the fact, however. While the title to our Act renders it applicable only to actions for damages for injury to persons *on* a street or other public place, the title to the Minnesota Act construed is merely: "An Act requiring a notice of claim for damages, to be given to cities * * * for loss or injury sustained in certain cases," and, while the first part of the Act is couched in the language employed in section 5080, down to and including "public works," our Act closes the enumeration of the places of injury with "public works of any kind," whereas the Minnesota statute continues: "or any grounds or places whatsoever, or by reason of the negligence of its officers, agents, servants or employees," thus broadening the scope of the Act to require notice of injury sustained in any place whatsoever by reason of any negligent act of the city. (See Chapter 381, Laws of Minnesota, 1913.) Although the fact conditions are similar, the dissimilarity in the Act construed renders the decision of no consequence in the decision of the question before us. It is noteworthy, however, that in 1929, the same court, under an amended statute (sec. 1831, S. S. 1923) which did not change the above language of the Act of 1913, held that the provision did *not* apply to an action for damages for injury received by a person who contracted typhoid fever as a result of sewage entering her cellar from a defective sewer pipe. (Hughes v. Village, 177 Minn. 547, 225 N. W. 898.)

As the requirement of notice is in derogation of a common right, no ruling on a statute requiring such notice is even persuasive unless the Act construed is substantially like unto our section 5080.

The requirement of notice to the city under statutes similar to section 5080 has generally been held not to apply to a case where the injury arises from the negligence of the city in carrying on, under legislative authority, a private, commercial enterprise, but only to claims arising from the carrying out of its governmental functions. (Henry v. City of Lincoln, 93 Neb. 331, 140 N. W. 664, 50 L. R. A. (n.s.) 174; Cook v. City of Beatrice, 114 Neb. 305, 207 N. W. 518; Borski v. City of Wakefield, 239 Mich. 656, 215 N. W. 19; Brown v. Salt Lake City, 33 Utah, 222, 93 Pac. 570, 14 L. R. A. (ns.) 619.)

Also, the statute requiring notice of an injury received or suffered

by reason of any defect in the "public works" of the city does not apply to facts such as we have before us. If plaintiff can prove his allegation that defendant knowingly furnished plaintiff with contaminated water he need not prove the source of the contamination, and hence need not give notice of the defect that caused the contamination. Thus "if a pile of road material were left by the city in the street in such a position as to turn the surface water in a stream upon abutting property, and a traveler was injured by coming in contact therewith, doubtless his cause of action would be properly said to arise out of a defective street; but the damage to the abutting property would arise out of the improper use of his property by an adjoining proprietor, precisely the same as if he were a private person, and without the remotest relation to the fact that such premises constituted a highway except for the purpose of identifying the culprit." (Muffley v. Village of St. Edward, 110 Neb. 572, 194 N. W. 461; compare, also, Randall v. City of Chadron, 112 Neb. 120, 198 N. W. 1020; Williams v. City of Nashville, 145 Tenn. 668, 238 S. W. 86; McCarty v. Town of Mountain View, 136 Tenn. 133, 188 S. W. 595.)

The presentation of notice to the city, as demonstrated above, was unnecessary.

4. Defendant's motion to strike certain paragraphs from plaintiff's complaint should have been sustained as to paragraphs VIII to XI, inclusive. Proof of the allegations made in these paragraphs may be made under the remaining allegations of the complaint. Hence paragraphs VIII to XI are immaterial and repetitious and should have been stricken. (Flatt v. Norman, 91 Mont.)

Plaintiff's motion to strike certain paragraphs from the answer should have been sustained in part. Paragraphs II to VI, inclusive, of the first special defense should have been stricken, for they were unnecessary in view of other allegations in the answer. The allegations there made can be proved under other allegations of the answer to refute the charge of negligence which was generally denied.

From what has been said, paragraph III of the second further answer or defense should also have been stricken.

The judgment is reversed and the cause remanded for further proceedings in accordance with the views herein expressed, with the right of either party to request and obtain leave to further plead if so advised.

ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Spot Tests for Lead. F. PAVELKA. Mikrochemie, 7: 301–4, 1929. From Chem. Abst., 24: 3965, August 20, 1930. Lead (0.001 milligram) can be detected by placing drop of nearly neutral solution to be tested upon filter paper which has been previously soaked in 0.5 per cent armoniacal solution of carminic acid, then exposing to ammonia fumes, and again drying. If lead is present violet spot is produced. Excess of copper prevents reaction but, by suitable modification of test, lead can be detected in presence of silver, bismuth or cadmium. Alternative test is to place drop of test solution on filter paper, and to add drop of dilute pyridine solution, followed by 0.1 per cent solution of gallocyanine. Spot is washed with successive drops of 1 per cent pyridine, when violet stain is formed in presence of lead. Lead may also be first precipitated on paper as sulfate and above test then applied, this method permitting detection of lead in presence of silver, copper, cadmium and bismuth.—*R. E. Thompson.*

Corrosion of Copper. I. L. W. HAASE. Metallwirtschaft, 9: 503–6, 1930. From Chem. Abst., 24: 3977, August 20, 1930. Review of literature on corrosion of copper, with special reference to corrosion in solutions in neutral range. Oxygen is generally required to cause corrosion since copper itself is not soluble in the liquids. However, copper oxide is soluble and, depending on nature of solution, the rate of corrosion is accelerated or decreased. Salts such as chlorides, nitrates, sulfates, and acetates, which form soluble compounds with copper, accelerate corrosion. Salts such as carbonates and hydroxides, which form insoluble products, tend to retard corrosion rates.—*R. E. Thompson.*

New Method for the Immediate and Instantaneous Determination of Metal Corrosion. F. TÖDT. Wärme, 52: 796–7, 1929; Wasser u. Abwasser, 27: 45; cf. C. A., 23: 1558, 4663. From Chem. Abst., 24: 3977, August 20, 1930. Corrosion and incrustation are determined by simple electric current measurement with zinc-iron circuit. Method is applicable to measurement of boiler incrustation by hard water.—*R. E. Thompson.*

The Mechanism of the Bactericidal Action of Chlorine. CARLOS A. SAGASTUME and ARTURO A. SOLARI. Rev. facultad cienc. quim. (Univ. La Plata),

6: Pt. 2, 71–3, 1930; cf. C. A., 24: 2490. From Chem. Abst., 24: 4069, August 20, 1930. Testing hypothesis that action of hypochlorite on organic substances gives rise to bactericidal radiations capable of acting through quartz, authors immersed suspensions of bacteria, in glass and in quartz tubes, in solutions of potassium hypochlorite and of potassium hypochlorite and urea. There was no evidence in support of theory, since presence of urea and use of quartz rather than glass did not increase any bactericidal effect.—*R. E. Thompson.*

Sodium Aluminate for Purification of Drinking Water. P. I. Vasil'ev. Zhur. Prikladnoi Khimii, 3: 207–19, 1930. From Chem. Abst., 24: 4106, August 20, 1930. Mixture of $Al_2O_3 \cdot (1.06\text{–}1.5)Na_2O$ and aluminum sulfate is better coagulant than latter alone. Experiments with water of river Neva showed that by using such mixtures time required for flocculation and precipitation of impurities is shortened, amount of active carbon dioxide in water is reduced, and utilization of aluminum is more complete. Proposed method permits treating water with larger quantities of aluminum than present aluminum sulfate method. More experimental work is required before method can be applied in practice.—*R. E. Thompson.*

Water Purification Methods in Cambridge, Mass. Haller. Stadt. Tiefbau, 19: 116–22, 1928; Wasser u. Abwasser, 27: 50. From Chem. Abst., 24: 4106, August 20, 1930. Very acid raw water is flocculated by $NaAlO_2$ and acidity neutralized with calcium carbonate. Purification works described.—*R. E. Thompson.*

High-Pressure Steam and the Boiler Water Problem. A. C. Purdy. Marine J., March 15, 1930. From Chem. Abst., 24: 4107, August 20, 1930. Boiler compounds are roughly classed into two groups on basis of composition: soluble salts of sodium and organic colloidal substances. Many compounds are worthless and all are sold at excessive prices. Hall system of treatment, consisting of controlled addition of commercial alkali phosphate, is highly recommended.—*R. E. Thompson.*

Fatigue Cracks and Boiler Plate. H. C. Dinger. Power, 71: 872–6, 1930. From Chem. Abst., 24: 4107, August 20, 1930. Illustrations show points of origin of fatigue cracks. Boiler design should take into account points of overstress, of periodic variations, and of corrosion.—*R. E. Thompson.*

Protecting Boilers from Embrittlement. J. J. Brennan. Power, 71: 908–9, 1930. From Chem. Abst., 24: 4107, August 20, 1930. Nature of crystalline aggregates formed by some sodium salts at high pressure and temperature may be related to their behaviour in forming protective films.—*R. E. Thompson.*

A Simple Water Softener. E. Walter. Destillateur und Likörfabrikant, 42: 650–1, 1929; Wasser u. Abwasser, 27: 50. From Chem. Abst., 24: 4106, August 20, 1930. Use of chemical softeners, permutite, electroösmosis, and Categulith as boiler scale preventives is discussed. Laboratory results favor Categulith.—*R. E. Thompson.*

Water Purification by Electrical Means. O. Riediger. Naturforscher, 1929: 314–6; Wasser u. Abwasser, 27: 50. From Chem. Abst., 24: 4106, August 20, 1930. Siemens electroösmosis process is described and its advantages are noted.—*R. E. Thompson.*

Apparatus for Taking Samples for Bacteriological Water Examination. G. Mirone. Zentr. ges. Hyg., 20: 662, 1929; Wasser u. Abwasser, 27: 35. From Chem. Abst., 24: 4106, August 20, 1930. Apparatus similar to official German sampler is described.—*R. E. Thompson.*

Pipe Line Corrosion. S. Gill. Petroleum Eng. 1: 9, 119–22, 1930. From Chem. Abst., 24: 4142, August 20, 1930. Condensed discussion dealing with few of the more important phases of present studies of corrosion of oil pipe lines, including soil composition, electric currents on pipes, and methods of protection. Results of practical corrosion experience are a most useful tool in developing methods of protection.—*R. E. Thompson.*

Application of Sodium Aluminate in Water Supply Systems of Pulp and Paper Mills. G. J. Fink. Cellulose, 1: 38–42, 1930. From Chem. Abst., 24: 4154, August 20, 1930. Review of influence of various impurities found in natural waters on different phases of the paper making process and discussion of advantages of sodium aluminate treatment.—*R. E. Thompson.*

Treated Water for Refinery Use. M. J. Japour. Petroleum Eng., 1: 9, 160, 1930. From Chem. Abst., 24: 4142, August 20, 1930. Successful zeolite softening on a large refinery scale is described.—*R. E. Thompson.*

The Effect of Electrolytes on the Bactericidal Action of Copper and Silver Salts. The Dependence of the Bactericidal Action upon the Electrostatic Charge of the Bacteria. An Explanation of the So-Called Salt Inhibition of the Oligodynamic Action. Nikolaus Leitner. Biochem. Z., 221: 42–63, 1930. From Chem. Abst., 24: 4320, September 10, 1930. It is shown that salt and acid inhibition of bactericidal effect of copper or silver salts is neither of chemical, nor of physico-chemical origin, but is due to action exerted by these added electrolytes on metal ions. Added electrolyte does not alter concentration of metal ions in solution; inhibition seems to be associated with hindrance to adsorption of metal ions by bacteria. It is suggested that for adsorption of electro-positive ions, intensity of the electrostatic charge on bacteria is of significance, in that the greater the negative charge, the more strongly are the metal ions attracted. Inhibition through electrolytes is then result of lowering of electric charge on bacteria. On this basis increased alkalinity should increase bactericidal effect of copper salts, a fact which has been experimentally verified.—*R. E. Thompson.*

The Sheffield (England) Water Supply. William Terrey. Munic. Eng. Sanit. Record, 84: 72–3, 1929: cf. C. A., 24: 1169. From Chem. Abst., 24: 4343, September 10, 1930. Water is filtered either through mechanical pressure filters, or through filter beds of crushed white quartz underlain with washed,

graded pebbles. Alumino-ferric and lime are employed as purifying agents.—*R. E. Thompson.*

Drinking Waters for Cattle. T. McLachlan. Analyst, **55**: 372–5, 1930. From Chem. Abst., **24**: 4344, September 10, 1930. Conclusion drawn is that water for cattle should be condemned only when bacteriological examination discloses bacteria known to be pathogenic to cattle.—*R. E. Thompson.*

The Selection and Operation of Pumping Machinery for Water Works. F. E. F. Durham. Engineering, **129**: 809–11, 839–41, 1930. From Chem. Abst., **24**: 4343, September 10, 1930.—*R. E. Thompson.*

The Ability of the Common Mackerel and Certain Other Marine Fishes to Remove Dissolved Oxygen from Sea Water. F. G. Hall. Am. J. Physiol., **93**: 417–21, 1930. From Chem. Abst., **24**: 4336, September 10, 1930. The toadfish is able to remove all measurable dissolved oxygen from water. In general, fishes remove dissolved oxygen to partial pressure of from 2 to 16 millimeters of mercury. Sluggish ones are capable of removing more, active ones, less of the dissolved oxygen.—*R. E. Thompson.*

The Respiratory Movements of Fish as an Indicator of a Toxic Environment. D. L. Belding. Trans. Am. Fish Soc., **59**: 238–45, 1929. From Chem. Abst., **24**: 4336, September 10, 1930. Respiratory rate bears direct relationship to water temperature and inverse one to size of fish. Rate is inversely proportional to oxygen content of water. Goldfish and carp are more resistant to decreased oxygen than trout. Lethal dose of hydrogen sulfide varied from 0.86 p.p.m. for trout to 25.3 p.p.m. for goldfish. Respiration is very irregular under influence of hydrogen sulfide. Lethal dose of hydrogen sulfide is inversely proportional to water temperature.—*R. E. Thompson.*

Free Active Chlorine in Water and Its Action on Fish and Other Water Animals. G. Ebeling and Th. Schräder. Z. Fischerei, **27**: 417–510, 1929; Wasser Abwasser, **27**: 95–6. From Chem. Abst., **24**: 4344, September 10, 1930. Death of large number of fish in River Spree was attributed to presence of free chlorine. Effect of bleaching powder, chlorine, and Caporite in various concentrations on fishes and crabs was determined in an aquarium. Lethal concentration for most fish lay between 0.3 and 1.0 p.p.m. free chlorine, with carp among the more resistant fishes. In general, 1 p.p.m. free chlorine killed minute Crustacea, rotifers, and diatoms; some other organisms were made ill, but recovered; while worms, mollusks, mites, and larvae of certain insects were totally unaffected. Effect of chlorine on hatching of carp eggs was also investigated.—*R. E. Thompson.*

Economics of Water Purification. E. Gross. Gas- u. Wasserfach, **73**: 601–6, 1930. From Chem. Abst., **24**: 4344, September 10, 1930. Careful consideration must be given to relation between capital and operating cost so as to secure lowest total purification cost per year. Bringing pure water from distant source is contrasted with purification of local (impure) source. Puri-

fication plants are discussed with respect to economical location. Screens may be used for removing floating material. Continuous sludge removal from purification plants is often desirable. Coagulating agent must be mixed rapidly and completely with water if rapid settling is to be secured. In some cases more rapid settling is secured by returning part of sludge previously separated. Rapid sand filters are discussed. These have almost entirely replaced slow sand filters. Size and purification of sand are discussed. Objections to chlorination are not valid.—*R. E. Thompson.*

The Rôle of Protozoa in the Autopurification Processes of Water Reservoirs from Pathogenic Organisms. N. A. Dmitrevskaya. Arkh. biol. naouk, **30:** 27-43, 1930. From Chem. Abst., **24:** 4345, September 10, 1930. A review and following conclusions. (1) Absorption of bacteria by protozoa in drinking water is experimentally established. (2) Bactericidal activity of protozoa depends upon nature of the water. Experiments reported deal with bactericidal effect of *Paramecium* upon cholera *Vibrio.*—*R. E. Thompson.*

Economic Balance in the Construction of Water Works Extensions. L. R. Howson. Eng. News-Rec., **106:** 851-3, May 21, 1931. Advisability of planning comprehensive water supply program is emphasized and examples are outlined. It is usually possible, by means of well-formulated construction program, to time successive additions so as to keep present worth of all expenditures at minimum and to collect the fixed charges from those who use the service and benefit therefrom. Average American water works involves expenditure of approximately $50 per person served. These construction requirements, when not sufficiently distributed, frequently result in inability to finance from current rates and involve costly delays. Average income of water works properties throughout the United States ranges from $6 to $6.50 per capita. Of this, $4 represents fixed charges, i.e., interest and depreciation. Cost of operation accounts for only 35 to 40 percent of total income. It is apparent that any program that will result in more uniform rate of capital expenditures and installation of betterments just prior to time at which they are needed has direct bearing on factor which amounts to nearly two-thirds of cost of water to consumer. Commission of engineers was recently appointed to study program under consideration in Cleveland involving expenditure of $60,000,000 during 10-year period. City is served by 2 tunnel intakes into Lake Erie and 2 filter plants having total capacity of 315 million gallons per day. Plan included new intake tunnel, pumping station, and 200-million-gallon-per-day filter plant on east side of city, to be completed by 1935, and similar construction on west side to be completed by 1939, latter to have initial capacity of 75 and ultimate capacity in 1960 of 150 million gallons per day. It was found that, through utilization of existing cross-town feeder mains, territory served by existing stations could be shifted farther west and construction of westerly plant thus deferred until after 1950. Revised program will save over $12,000,000 in interest alone prior to 1950. In Chicago, present system is incapable of maintaining pressures during periods of heavy demand; yet should universal metering be adopted, it would be overbuilt from water works standpoint. Existing intake tunnels, pumping stations, feeder and

circulating mains would be adequate for next 30 years if waste could be eliminated. Present average per capita pumpage is 310 gallons per day. Construction of filter plants, as approved in election of November, 1930, in advance of waste reduction, would involve expenditure of from \$30 to \$40 millions more than if waste restriction should precede filtration. It has been estimated that over \$200,000,000 could be saved during next 20 to 30 years by comprehensive plan of waste restriction. Typical example of well-developed plan is Mokelumne River project of East Bay Cities. This supply is considered adequate until year 2000, at least. One principal item of expense is 90-mile conduit which will carry, according to present estimates, 30 million gallons per day in 1938, 50 in 1947, 75 in 1956, 125 in 1973, and 200 in 2000. Program provides for 30-million-gallon-per-day conduit in 1926, installation of booster pumps in 1938 to overcome excessive friction, second conduit in 1947, operating both by gravity until 1956, when boosting pressure will again be adopted, and third conduit in 1973 to provide up to 125 million gallons per day by gravity flow or 200 if boosted. Excellent example of comprehensive program financed from plant earnings is afforded by Racine, Wisconsin. Works were inadequate and water quality poor when property was acquired by city in 1919, and 10-year program then developed required estimated expenditure of \$1,935,800. First unit of construction was coagulation basin, which materially improved quality of raw Lake Michigan water. This was followed progressively by 36-inch intake, 7000 feet into lake, 12-million-gallon filter plant, 3-million-gallon low-service reservoir, and 2.75-million-gallon high-service standpipe. Bids are now to be taken on electric pumping station and 8-million-gallon-per-day filter plant extension. All these improvements have been financed from earnings. Louisville has for many years financed new work wholly from earnings, operating under rate schedule in which discount rate on consumers' bills is varied from 10 to 33 percent, depending upon construction requirements, base rate remaining constant. Under this plan an 84-million-gallon-per-day filter enlargement, pumping station, etc., has been financed and reservoir and main extensions are underway.—*R. E. Thompson.*

Can Cement Durability be Predicted? E. T. Carlson and P. N. Bates. Eng. News-Rec., 107: 130-2, 1931. Study was made of 138 samples of cement, representing 24 brands made in 31 mills, to determine value of method suggested by Merriman (cf. C. A., 24: 1718) for determining cement durability. Complete analyses of the cements were also made and their compound composition calculated according to method of Bogue (cf. C. A., 23: 5556). Results obtained, which are tabulated, bear out in many respects predictions of Merriman. In general, cements which had low "index of disintegration" were more resistant to Na_2SO_4, but variations were so great that it would be impossible to predict behaviour of a given cement from its index. Relation somewhat similar to that found by Merriman between Al_2O_3 content and disintegration index was noted between resistance to disintegration and calculated content of $3CaO \cdot Al_2O_3$. Cements high in $3CaO \cdot Al_2O_3$ were, as a rule, first to disintegrate, but results varied to such an extent as to be of little more value than as indicating general trend. It was found difficult to secure consistent duplications of titration results. Authors conclude that it is doubtful

whether index is indicative "of the completeness with which a cement has been manufactured." As the cements are being used on government projects, results can be compared with durability in the field after lapse of some years.—*R. E. Thompson (Courtesy Chem. Abst.)*.

Better Methods of Testing Cement Needed. NATHAN C. JOHNSON. Eng. News-Rec., 107: 304, August 20, 1931. Brief discussion of results obtained by CARLSON and BATES (cf. previous abstract) in study of MERRIMAN's proposed method for determining cement durability. Need for such a test is stressed. Variations noted by CARLSON and BATES are not as great as those commonly reported with the so-called standard tests. Discrepancies, however, indicate that test needs to be simplified and improved.—*R. E. Thompson (Courtesy Chem. Abst.)*.

Report on the Working of the Water Analysis Laboratory, Corporation of Madras, 1931. S. V. GANAPATI. 6 pp. Results of examinations of raw and treated waters are given in tabular form and briefly discussed. As in former years, treatment employed consisted of prechlorination and slow sand filtration. As usual [cf. THIS J. 24: 2048], H_2S was present in filtered water chambers, etc., and growths of *Beggiatoa* and *Thiothrix* were found wherever H_2S was produced. Filter runs averaged 46 days, and daily consumption was 19.46 million gallons.—*R. E. Thompson.*

Jute Causes Trouble. GEORGE I. WHITE. Water Works Eng., 85: 24, 1420, November 30, 1932. New reservoir at Kalamazoo, Michigan, was sterilized by spraying walls with water containing 40 p.p.m. residual chlorine and addition of chlorine during filling. Fittings were jointed with lead: at all other joints, dresser couplings were used. Water containing 40 p.p.m. chlorine was used to sterilize. After flushing and refilling reservoir and mains, *B. coli* was still present in 1 ml. Repeated sterilization seemed without effect. Jute packing was then examined and showed presence of *B. coli* in 0.05 gram. Continued chlorination of mains has somewhat relieved the situation.—*Lewis V. Carpenter.*

Treatment of Well Waters. M. J. DAVIS. Water Works Eng., 85: 24, 1414, November 30, 1932. Supply of Wellsburg, W. Va., is obtained from two Layne wells twenty-four inches in diameter and seventy feet deep by motor-driven vertical centrifugal pumps. Water is hard and contains iron. Treatment consists of aëration, filtration, and softening. Tray aërators, pressure filters, and pressure zeolite filter are used.—*Lewis V. Carpenter.*

Payment of Water Bills. LEO T. PARKER. Water Works Eng., 85: 25, 1471, December 14, 1932. Water company not having authority under state laws to make water charges a lien on premises supplied has no right to refuse to supply water to mortgagee, or to purchaser, who fails to pay arrears of rates against property. Water company, or municipality, suing to recover payment for water in virtue of ordinance enacted subsequently to use of water will be non-suited. Ordinance requiring property owner to pay all water bills

is void, unless authorized by state law. Same rule applies with respect to municipal, or water company, regulations. Court held that lease contract obligated tenant to pay water bill, instead of owner of property. Tenant is not liable for payment of water bill if he proves that water leaked from source over which he had no control: he is bound, however, to prove the leakage. State law may make charge for water furnished tenant a lien upon the property; in which case owner is liable for payment.—*Lewis V. Carpenter.*

Law of Water Works Construction. LEO T. PARKER. Water Works Eng., 85: 26, 1525, December 28, 1932. Construction contract shall be interpreted in light of intended meaning of contracting parties at time when contract was originally made. All agreements are void which tend to restrain natural rivalry and competition of contractors who bid on public construction contracts. Law is settled, that municipality is not liable on implied construction contract, if such contract is in violation of city charter. Municipal warrants signed by proper officer are prima facie valid and establish prima facie, though not conclusively, validity of claims for which they are issued, so as to cast on municipality burden of proving defense of invalidity. Contractor is entitled to rescind, or cancel, a bid and demand return of deposit at any time before his bid is accepted. No person has vested, or implied, right to work for state, or for any of its public agencies, upon public work. Such right is privilege granted by, or under, authority of state and may be granted under terms and conditions not in conflict with state law. Law requires architect, or engineer, to exercise ordinary care in preparation of plans and specifications: he must, moreover, be reasonably competent and efficient in performance of his work.—*Lewis V. Carpenter.*

New Pittsburgh Pumping Station. L. J. LAMBERGER. Water Works Eng.; 85: 26, 1518, December 28, 1932. City of Pittsburgh recently dedicated its new electric Brilliant Pumping Station. With installed capacity of 160 m.g.d. in six units, station is, from power standpoint, largest in Pittsburgh's water system and one of largest electrically driven stations in country. Architecturally appropriate and very attractive design was achieved. Special care was given to illumination and to convenience and comfort of operating force. Pumping units are simple and compact. Each of four pumping to Highland Reservoir No. 1 has rated capacity of 28 m.g.d. against head of 365 feet, consisting of 2250-h.p., three-phase, 2300-volt, synchronous motor connected to two 24-inch by 30-inch centrifugal pumps in series. Each of other two, pumping to Highland Reservoir No. 2, has rated capacity of 24 m.g.d. against head of 272 feet, consisting of 1500-h.p., three-phase, 2300-volt, synchronous motor connected to two 24-inch by 30-inch centrifugal pumps in series. Speed of all units is 220 r.p.m. Outstanding features of substation are its simplicity and low cost per unit of capacity. Investment was approximately $770,580, or about 45 per cent of cost of alternate system studied, namely, of steam-driven station. Power cost is $198,000 annually.—*Lewis V. Carpenter.*

Water Works Accounting. M. F. RUNNION. Southwest Water Works Jour., 14: 10, 20, 1933. Method used in municipal plant of Greenville, Texas.—*O. M. Smith.*

Allocation of Water Revenues and Its Relation to Public Safety. H. R. F. HELLAND. Southwest Water Works Jour., 14: 10,14–15, 1933. Measure all consumption regardless of use and enter charges accordingly. Records should show operation costs, maintenance, depreciation, taxes, fixed charges, and profits.—*O. M. Smith.*

Problems in Water Plant Operation. E. M. RATLIFF. Southwest Water Works Journal, 14: 12, 7, 1933. General discussion on public relations, collection of accounts, fire protection, salaries, meters, and Board of Health regulations.—*O. M. Smith.*

Modern Practice in House and Service Connections. A. R. DAVIS. Southwest Water Works Journal, 14: 12, 9–10, 1933. Procedure followed at Austin, Texas.—*O. M. Smith.*

Modern City Practice in House and Service Connection. J. L. HORNER. Southwest Water Works Journal, 14: 12, 11, 1933. Results of questionnaire sent to 39 Texas cities.—*O. M. Smith.*

Copper Service Pipe in Water Systems. T. G. BANKS. Southwest Water Works Journal, 14: 12, 13–16, 1933. Copper tubing has been used in Oklahoma City since 1925: is most satisfactory material yet developed for water service and fulfills every requirement.—*O. M. Smith.*

Water Works Accounting Methods. W. L. IRVIN. Southwest Water Works Jour., 14: 7, 35, 1932. General outline is given, which may be used to advantage as basis for uniform classification for water works accounting system.—*O. M. Smith.*

Installation and Repair of Water Mains. W. H. WARING. Southwest Water Works Jour., 14: 6, 13, 1932. Personal opinions gathered from eight years' experience with cast iron pipe in Dallas, Texas, Water Works Department. *O. M. Smith.*

The Fort Worth, Texas, Water Supply System. ANON. Southwest Water Works Jour., 14: 7, 13, 1932. System described.—*O. M. Smith.*

Reservoir Construction and Maintenance. A. H. WOOD. Southwest Water Works Jour., 14: 11, 13, 1933. Description of three clear water reservoirs for City of El Paso, Texas. Largest is circular concrete tank, 20 feet deep by 140 feet in diameter reinforced with many external bands of 1-inch rod joined by turn-buckles and covered with 1½ inches of gunite. Roof is internally unsupported concrete dome with rise of 17 feet. All openings and vents are rendered dust proof with felt and fine copper screens.—*O. M. Smith.*

Phoenix, Arizona, Water System Improvements. W. J. JAMIESON. Arizona Public Health News, 64, 65, June, 1931. Phoenix, Arizona, is constructing an addition to her reservoir which will increase the capacity from 15 to 30 million

gallons per 24 hours. The flow lines to the reservoir are likewise being similarly increased. Two plants were installed for making centrifugally cast reinforced concrete pipe. Another plant was erected to supply Hume steel pipe. Steel plates $\frac{3}{16}$ of an inch thick and of various lengths are made into pipe of the required diameter. The steel pipe is lined with concrete, and the exterior is wrapped with wire mesh and gunited to a thickness of $\frac{3}{4}$ of an inch. The reservoir, two tunnels, pipe lines, and detritor will cost $2,059,150.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

Improving Miami's Water Supply. Roy Gilbert. Arizona Public Health News, 64, 67, June, 1931. Two large copper mines are located at Miami, Arizona, and for a considerable period the mining region was greatly handicapped due to an inadequate water supply. Several test borings made in a nearby valley showed a limited supply of potable water. A plentiful water supply was obtained by sinking a shaft to bedrock and radiating long drifts from the bottom, so that the water percolating along on top of the hardpan could be collected.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

Efficacy of Water Chlorination at Chicago: Dosage to Be Used. Ed. Imbeaux. Rev. D'Hyg. Med. Prev., 53: 281, 1931. A review of Gerstein's report presented at the St. Louis meeting of the American Water Works Association. The term "Verdunisation" is disclaimed as unscientific on grounds of the earlier works of Darnall (1912), Lode (1894) and Traube (1894).—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

Oberhaus Water Works with Quick Filter Plant and Infiltration Plant for Augmenting Ground Water. Heinrich Kring. Gas u. Wasserfach. 74, 193, 1931. Chemical Abstracts, 25: 11, 2788, June 10, 1931. "Costs of operation are given for filter and infiltration plants and details of operations. Illustrated."—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

Determination of Phenols in Water Solution. J. A. Shaw. Industrial and Engineering Chemistry, Anal. Ed., 3: 3, 273. July 15, 1931. The bromine method as ordinarily used, is not readily applicable to samples containing less than 75 p.p.m. of phenol. The proposed variation in procedure consists simply in concentrating the phenols into caustic soda by means of ether washes, heating the sodium hydroxide solution to drive off the ether (and certain other impurities) and then applying a previously published method (Shaw, 1929, Ind. Eng. Chem. Anal. Edit., 1.118). Phenols may be determined in concentrations of 1 p.p.m. or even less.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

Development of Water Supplies by the Southern Pacific Company. R. Benzie. Arizona Public Health News, 64, 61, June, 1931. The dug wells in Arizona and New Mexico vary in depth from 20 to 200 ft. Most of the water, from a chemical standpoint, is of fair quality, or contains considerable hardness. When an increased demand was made for more water and of better

quality, drilled wells were started. Depths of 400 to 1800 feet were used and a good supply of water was obtained.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

The Chlorination of the Water Works at Antung, Manchuria. K. OKUDA and others. Journal of Public Health Association of Japan, 7: 4, 1, April, 1931. The filtration plant at Antung, Manchuria, began operation in October, 1925. In spite of chlorination a persistent odor existed, which led to a series of experiments which were made to determine the variation of the chlorine content in the reservoir, the number of organisms, the amount of chlorine in a hydrant on the supply and the effectiveness of the filter beds. Some of the results of these experiments are as follows: It was decided that the correct amount of chlorine to be used for disinfection should be 0.2 to 0.26 p.p.m., the odor problem, while not solved, was believed to be due to organic substances and an excess of chlorine; weeds and water grasses in the raw reservoir were recommended for removal.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

Laboratory and Epidemiological Study of a Bacillary Dysentery Outbreak. JOHN MOTE. Arizona Public Health News, 64, 8, June 1931. "We may say that a bacillary dysentery primarily of the Shiga type was observed in Tucson between April 20 and May 10, 1930. Of a population of 246 persons at the Desert Sanatorium 29, or 11.8 percent reported gastrointestinal upsets with diarrhea. An epidemiological survey indicated by circumstantial evidence that the condition was a milk-borne infection with a contaminated water supply at the dairy as a possible source. It should be emphasized that with the method of sterilization and pasteurization commonly used in this section, the water supply of producing and distributing dairies should be controlled."—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

The Algae—Again a Menace. Monthly Bulletin of the Philippine Health Service, 11: 2, 97, February, 1931. Last summer a pestilent odor from decomposed algae in the small salt water rivers invaded the city of Manila. The article states that algae are appearing again this season and if dry weather continues a repetition of the foul odors may be expected. It is believed the nuisance can be prevented if the contemplated dredging of these rivers is started at once.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

Increase of Amoebiasis during the Rainy Season in Puerto Cortez, Honduras. K. C. BREWSTER. United Fruit Company Medical Department, Nineteenth Annual Report 1930. An examination of some 6,000 people during the dry season and the following rainy season showed an infection of 25 percent average at the end of the dry season increasing to 69 percent as the rainy season advanced. Sanitary conditions were bad and amoeba were found practically wherever looked for. There seems to be a close relation between increased rainfall and increased amoebic infection in a community where amoebiasis is endemic.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

New Metalo-chlorination Process for Sterilizing Swimming Pools. W. Olszewski. Pharm. Zentralhalle 71, 171, 1930. Chemical Abstracts, 24: 13, 3303, July 10, 1930. "An alleged improvement on the Krause method (Cl–Ag) for rendering swimming pools germ- and fungus-free consists in the partial substitution of Cu for a portion of the Ag, thus rendering the treatment just as effective and at the same time cheaper. References are cited which give the particular type of chlorinator involved.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

The Control of Rushes and Water Lilies in Localities Infested with the Bilharzia Parsaitic Worms. F. G. Cawston. Journal of Tropical Medicine and Hygiene, 34: 6, 84, March, 1931. The destruction of the bluewater lily Nymphaea Stellata, and of the broad rush of river banks, Cyperus immensus, is urged. Control of these plants, the favorite foods of the common snail hosts of bilharzia parasitic worms, would be a great move forward in tropical sanitation. Burning the rush in the dry season and removal of the roots of the water lily as a method of controlling its reproduction are suggested.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

River Pollution from the Standpoint of Water Undertakings. A. R. Atkey. Journal Royal Sanitary Institute, 51: 7, 415, January, 1931. The speaker presented to the Royal Sanitary Institute's Conference on the pollution of Rivers and Streams his appeal for the further establishment of river boards for the control of pollution of streams. It is his claim that the delay in establishing such bodies is largely due to the self satisfied attitude on the part of local authorities who believe "they are doing their share in that bit of river which happens to pass through their territory, oblivious to the fact that the pollution may not occur within their area." He also expresses the thought that one of the problems of water engineering is not the demands and needs of the moment, but the demands that may arise in from 10 to 40 years' time.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

Weather Conditions as Factors in the Filtration of the Water Supply at Detroit, Michigan. Bert Hudgins. Monthly Weather Review, 58: 9, 354, September, 1930. Weather conditions are shown in this article to greatly modify the condition of the raw water furnished to the Detroit filtration plant. The intake is located at the head of Belle Isle, near the outlet of Lake Saint Clair. This lake, a shallow one, is readily stirred up by winds of 20–30 miles per hour and results in rapid increases in turbidity and bacterial content of the water. "Thaws in winter cause ice to break loose from shores and streams to swell with polluted waters, bringing great quantities of sewage to the lake and water intake." Rainstorms flush out polluted tributary streams and in spring the break-up of ice in the upper lakes produces much pollution. Winds also have caused reversals of flow of the Detroit River thereby carrying local pollution up stream to the intake. A study of the above conditions, from a comparison of weather records and filtration records shows the influence of these various factors on the water supply.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

The Epidemiology of Cholera, with Special Reference to Transmission. A Preliminary Report. C. A. GILL and R. B. LAL. Indian Journal of Medical Research, 18: 4, 1255, April, 1931. It is admitted by the authors that cholera in India has not declined appreciably since 1877, and that a disease now causing an annual loss of life of 300,000 in India demands further study. The persistence of cholera in view of the control methods applied suggests an unknown vector, and the house fly comes under suspicion. Explosive types of outbreaks can well be accounted for as water-borne, in view of the well-known epidemics from this source, but protracted outbreaks cannot be satisfactorily explained by the water-borne theory.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

Bacillary Dysentery in Great Britain. J. A. CHARLES. Public Health (Official Organ of Society of Medical Officers of Health) 44: 8, 247, May, 1931. Dr. Charles thesis is that bacillary dysentery is an endemic disease in certain parts of Britain. Historical data on dysentery with important discoveries regarding it, the work done in Aberdeen, Glasgow and in Newcastle-upon-Tyne, including clinical, epidemiological and bacteriological evidence, are covered in the paper.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

Effect of Particle Size on Capacity of Zeolite. PAUL BIRD, FRANK COLBURN, and FRANK SMITH. Ind. Eng. Chem., 25: 564, 1933. As expected, softening capacities of 4 artificial zeolites were found to vary inversely with particle size, surface area per unit volume being greater, the smaller the particles.—*Edw. S. Hopkins.*

Application of Statistics to Problems in Bacteriology. I. A Means of Determining Bacterial Population by the Dilution Method. H. O. HALVORSON and N. R. ZIEGLER. Jour. Bact. 25: 101, 1933. Development of equations for evaluation of *B. coli* density by dilution method is discussed. Tables are given.—*Edw. S. Hopkins.*

Relation of Changes in Morphology and Metabolism in B. Coli. WILLIAM F. LANGE. Jour. Bact. 25: 123, 1933. According to this study, *B. coli* grown in synthetic medium may show differing reactions to GRAM stain. Additional information is needed to explain this condition.—*Edw. S. Hopkins.*

The Disappearance of the Coli-Aërogenes Group in Natural Purification Processes as Determined by Direct Plate Counts. C. C. RUCHHOFT, E. W. COULTER, C. L. ADAMS and A. L. SOTIER. Jour. Bact. 25: 143, 1933. Bacterial survey was made of samples ranging from raw sewage of Chicago plants to water from point in Illinois river for about 125 miles below Lockport. In all cases inoculation ensued into standard lactose broth and on to NOBLE medium within 4 hours after collection. Growth on eosin methylene blue plates and subsequent gas formation in brilliant green tubes were used to confirm lactose presumptives. Direct plate counts gave lower, and probably more accurate, *B. coli* densities. Conclusion is that self-purification in streams, including dilution, effects little change in ratio of *B. coli* to *B. aërogenes* from

that pre-existing in sewage, necessity for their differentiation being therefore slight.—*Edw. S. Hopkins.*

Some Results on the Use of Crystal Violet in Bacteriological Culture Media for Water Analysis. C. N. Stark and C. W. England. Jour. Bact. 25: 439, 1933. When Salle's gentian violet medium was inoculated with pure cultures of *B. coli* obtained from fresh feces and incubated at 37°C., forty-three percent of tubes tested gave negative results after 48 hours incubation, while parallel inoculations in lactose broth gave positive results in all cases. If, however, Salle broth tubes were held for about 5 days, fermentation occurred; indicating that growth was initially inhibited. These results are held to militate strongly against adoption of Salle's crystal violet broth for water analysis.—*Edw. S. Hopkins.*

Natural Filters at Perth, Scotland. Cyril Walmesley. Water & Water Eng., 35: 417, 237–42, 1933. Site of infiltration galleries in gravel bank is such that, with river at normal levels, water must percolate into them through horizontal thickness of sand and gravel of over 100 feet: whereas, with flood conditions, this distance is reduced to 10 or 12 feet. Chlorination is practiced, after filtration, using dosages of from 0.2 to 0.9 p.p.m., without taste complaints. Monthly bacteriological tests are made. Chemical analysis indicates a moderately hard water.—*Edw. S. Hopkins* (*Courtesy Chem. Abst.*).

Deep Tunnels for Delivery of Water Supply. Walter E. Spear. Civil Engineering, 3: 122–125, March, 1933. As modern city increases in size, it may become increasingly difficult to find room in streets for large trunk water mains necessary. In New York, 66-inch pipe is about as large as can be comfortably laid in streets without interfering with sewer connections. It may not be entirely safe to build rapid transit subway in same street with large water pipe. Conduits 10 feet, or more, in diameter may be built in open cut. Such construction will create as much disturbance as that of a subway and its cost will be high. Tunnels of large diameter may be built in soft ground much deeper than is possible in open cut. When conditions permit, ideal solution for this problem is found in deep pressure tunnels in rock, lined with masonry, advantages of which are many. Theoretically it would be safe to construct a pressure tunnel in sound rock with minimum cover of 50 feet, provided that additional overburden of broken rock would add sufficient weight. Sound rock cover of not less than 150 feet appears to be safer basis of design. Masonry lining is necessary in order to provide permanent support for rock and smooth waterway. Pressure tunnels in rock are cheaper than pipe lines of equivalent capacity laid in streets and less liable than pipes or earth tunnels to damage and interruption from other construction or from earthquakes.—*H. E. Babbitt.*

Coagulants for Water Purification. Manufacture and Control of Liquid Alum. James W. Armstrong. Civil Engineering, March, 1933, 3: 168. In making liquid alum, it is only necessary to bring together the ingredients in such way that resulting chemical actions can be watched and controlled. No artificial heat has ever been used at Montebello, that generated by mixing of

the chemicals being sufficient to complete the reactions. Proportions of 575 pounds of bauxite and 1120 pounds of 60-degree Baumé sulfuric acid diluted with about 50 pounds of water were used as the equivalent of one ton of lump alum. For making the alum, three tanks of identical design, each having capacity of 19,800 gallons are used. They are made of $\frac{5}{16}$-inch steel plate and are lined with 10-pound sheet lead. Two lead-lined steel tanks, 5 feet in diameter, each holding enough acid for making one batch of alum, are used for measuring acid. About eight tons of alum are made in each batch. Entire process requires about 90 minutes. It was found necessary to replace all cast-iron alum pipe lines with solid lead, and to use only solid lead valves. Net cost per ton of liquid alum was $11.62.—*H. E. Babbitt.*

Formation of Floc with Ferric Coagulants. Edward Bartow, A. P. Black, and W. E. Sansbury. Civil Engineering, 3: 171, March, 1933. It has long been recognized that ferric coagulants can be employed for removal of color or turbidity from natural waters, but only in recent years have they become available at prices to compete with alum. In coagulation, or formation of floc, the action of ferric salts is very different from that of ferrous sulphate. Insolubility of ferric floc not only begins at lower pH than that of alum floc, but also persists, unlike latter, at higher pH. Available pH range for floc formation is therefore decidedly broader on both sides of neutrality for ferric salts than for alum; while its higher specific gravity shortens sedimentation periods necessary.—*H. E. Babbitt.*

Chemical Processes in Water Supply. Alexander Potter. Civil Engineering, 3: 179, March, 1933. Increasingly difficult problem of securing proper sources of potable water is driving certain water purification plants in New Jersey on to dilute sewage as raw material. At times, in one plant, *B. coli* index of over 601,000 per 100 cc. is found. Chemical treatment of sewage is advocated as panacea for this situation.—*H. E. Babbitt.*

Standard Well Specifications Issued by National Association. The Johnson National Drillers Journal, December, 1932–January, 1933. Prepared jointly by American Specifications Institute and American Association of Water Well Drillers, specifications are intended to cover the drilling, casing, and finishing of wells which obtain their supply from either sand and gravel or rock formations. They are divided into seven sections, as follows: (I) Contract and Legal, (II) Economic (III) General Description, (IV) Preliminary Preparation, (V) Materials, (VI) Design and Construction, and (VII) Results.—*H. E. Babbitt.*

Lateral Sedimentation. James W. Pearl. Pamphlet; published by author. Lateral sedimentation is term coined to cover method of collecting extremely fine solids, when freely floating or suspended in fluids, by local attraction, in any direction and either with or without aid of gravity. Mathematical inquiry into the horizontal forces determining equilibrium of small solid particle supported in fluid, based on sole principle that mutual attraction between any two masses of matter varies directly as their product and inversely as square of distance between their centers of gravity.—*H. E. Babbitt.*

Athens Builds Modern Water Works. R. W. Gausmann. Civil Engineering, 3: 1, January, 1933. Water works history of the city precedes description of modern project, most spectacular part of which is Marathon dam, the only large, marble-faced dam in the world. It is 935 feet long and 177 feet high. Water is led from reservoir through tunnel 8.4 miles long, with horseshoe section 8.1 feet high by 7.5 feet wide. From south end of Boyiati tunnel, aqueduct reduces in size to height of 5.25 feet for 1½ miles, and then continues in 36-inch c. i. pipe for 3.4 miles. Completely new distribution system was installed to deliver 26 gallons per capita per day, requiring 533 miles of cast iron pipe, and 55,000 house connections of flexible copper tubing. Each service is metered. It is believed to be largest single pipe laying job ever undertaken. Water is filtered through 15-m.g.d. rapid sand filter. Entire cost of project was about $11,000,000.—*H. E. Babbitt.*

Profile for a Low Dam Determined by Models. Albert W. Newcomer. Civil Engineering, 3: 9, January, 1933. In planning Cochiti Diversion Dam, Conservancy District undertook to determine, by means of experimental flume and models, shape and elevation of apron best suited to prevent erosion below dam. Flow of 14 to 20 second-feet was available through flume. Ratio of 1:10 was used for models and ten different models were tested. It was finally concluded to use flat apron instead of the bucket type which, before tests were made, had been thought most suitable.—*H. E. Babbitt.*

Initial and Final Dam Heights. E. H. Burroughs. Civil Engineering, 3: 14, January, 1933. Experiences with dams in service have shown that greater storage and higher head than were originally anticipated are often required. Generally speaking, most masonry dams can be raised substantially without reduction of safety factor. Methods commonly used for this purpose are: (1) flash boards, (2) crest gates, or (3) additional concrete structure. Ambursen-type dams may be increased in height by extending the buttresses down stream and adding water-bearing deck to whatever new crest height may be indicated. It is economical to build low dams for three reasons: (1) cost of raising is properly carried by posterity, (2) extensions to dam can be performed when labor and material costs are low, and (3) tax-payers will more readily vote for the lower bond issue required for construction of the lower structure.—*H. E. Babbitt.*

Preventing the Disintegration of Dams. Oren Reed. Civil Engineering, 3: 26, January, 1933. Effects of temperature changes and of frost action on saturated concrete are causing damage to concrete dams. When air temperature falls, temperature difference results between interior of dam and surface, causing stresses and formation of hair cracks. Water seeks its way through these cracks and dissolves portions of the cement. Decomposition of cement may proceed to a complete breakdown. In many rivers, iron and manganese carbonates are present and are easily oxidized by air, setting free carbon dioxide which strongly attacks concrete. Means to prevent destruction of concrete include: (1) water-resistant cement; (2) water-tight concrete; (3) application of water-tight, elastic, and durable coating to upstream face of

dam. Conditions at many Scandinavian dams are discussed, together with methods of cement manufacture, and of water-proofing. Water-proofing membranes of paper are suggested. Ringedals dam was protected by constructing water-tight slab 6½ feet in front of old dam. Investigations indicate clearly that if the concrete is made and placed in such way as to avoid percolation of water, there is no ground for supposition that portland cement, at least under normal circumstances, cannot be regarded as sufficiently durable material for hydraulic structures.—*H. E. Babbitt.*

Court Decisions Relating to Public Health. Public Health Reports, **47**: 21, 1152, May 20, 1932. **City Liable for Sewage Pollution of Stream.** (1) Oklahoma Supreme Court; Oklahoma City *v.* West, 7 P (2d) 888; 1931. Riparian owner filed suit against city to recover damages resulting from discharge of unpurified sewage into stream. Judgment for plaintiff. (2) Riparian owner filed suit as above. It was contended that since sewer system is permanent structure, if negligence is not proven in plans or construction, nuisance is not permanent. Damage not caused by structure but by the manner of its use. City of Mangun v. Sun Set Field, 73 Okl. 11, 174 P. 501, to the contrary, is overruled. (3) Since sewage can be purified by modern appliances, such an act is a temporary nuisance. It is unlawful for municipality to continue discharging unpurified sewage into stream to damage of riparian owner, and require the nuisance to be held to be permanent.—*R. E. Noble.*

Sanitation at the Yorktown Sesquicentennial Celebration. Arthur P. Miller. Public Health Reports, **47**: 28, 1471, July 8, 1932. **Water Supply.** Yorktown having no water supply, authorities contracted for 700 g.p.m. from well drilled on celebration grounds, which, however, proved, both quantitatively and qualitatively a complete disappointment. A 200-g.p.m. pump was therefore installed at an artesian well on York River beach and all arrangements, including chlorinator, were made for emergency supply in case of need from surface-fed Wormleys Pond. Distribution system was laid down to supply kitchens, shower baths, drinking fountains, and other necessary points. Notwithstanding prechlorination of system, bacterial results were initially unfavorable, hence chlorine was applied to pump suction, thus securing safe drinking water. Three groups of sanitary fountains were placed at positions convenient to grand stands and single fountains throughout the grounds and in the Village of Yorktown.—*R. E. Noble.*

The Activated Carbon Method of Water Treatment. F. E. Stuart. Pamphlet of Industrial Chemical Sales Company. Even the most obstinate cases of taste and odor trouble may generally be relieved by treatment with powdered activated carbon (P. A. C.). An ordinary charcoal particle, somewhat resembling coal, developes upon activation an enormous area of external and internal adsorptive surface. Thus it has been reckoned that one cubic inch of Aqua Nuchar, for water treatment, produced from cellulose, one gram of which contains about 92,500,000 particles, possesses a superficial area of 20,000 square yards. First practical success in carbon treatment in U. S. A. was achieved by John R. Baylis in 1929 at Chicago Experimental Filter Plant, using

granular carbon. George R. Spalding later in same year successfully used the new material in powder form at New Milford, N. J., Filter Plant. Since then its use has rapidly increased. P. A. C. is usually applied suspended in minor flow of water to be treated by means of either (*a*) ordinary dry-feed machine, with solution-box, or with water-operated ejector; or (*b*) solution-tank, fitted for continuous agitation, either mechanical, or by compressed air. For quickest relief in emergencies, or for short periods, P. A. C. may be applied to filter influent. Filter runs may thus be shortened, but are often unaffected. Aid by prechlorination is recommended. In coagulation processes, use of P. A. C. has been observed to effect: (*a*) stabilization of sludge; (*b*) control of chlorine demand; (*c*) reduction in residual alumina; (*d*) reduction in coagulant dosage required; and (*e*) widening of pH zone for successful floc formation. While prechlorination materially aids in taste control and in sludge stabilization, yet carbon alone may render sludge odor less. Sludge putrefaction at summer temperatures liberates gases and causes tastes and odors which are amenable to P. A. C. treatment. It has been proven that P. A. C. in moderate doses in settling basins, has no dechlorinating action, but, on the contrary may reduce chlorine consumption. It has also been found efficacious in reducing residual alumina. Apart from stabilization of sludge, small amounts of P. A. C. used with coagulant increase efficiency of coagulation, often with saving of alum. P. A. C. is now being used in 400 plants. It has sometimes been applied at two different stages in treatment process. Dosage usually runs from 8 to 24 pounds per m.g. (i.e. from 1 to 3 p.p.m.). Instances of remarkable savings are quoted. Method of treatment of fairly general application is outlined in which advantage is taken of fact that P. A. C., though it has little dechlorinating action in suspension, has strong dechlorinating action when deposited on filters.—*R. E. Noble.*

The Water Supply of the City of Bern, Switzerland. Wasser und Gas, 22: 2, 70, October, 1931. Water Supply of City of Bern is shown by documentary evidence to date back to about 1403 A.D. Present supply is made up partly from the old supply taken from a large number of small springs in one district and partly by drawing upon an underground basin in the Emmen-valley, which delivers daily 36,000 cubic meters of ground water, from wells 52 feet deep and at a distance of 120 to 240 meters from river, and is fed from catchment area of 197 square kilometers. Water from old spring district is chlorinated with dose of 0.1 p.p.m. and daily samples are taken for bacteriological examination.—*Manz.*

About the So-Called "Water-Borne Disease." Kathe und Königshaus. Archiv. f. Hygiene und Bakteriologie, 109: 1, 1, October, 1932. In a settlement with its own water supply, a sudden epidemic of feverish gastro-intestinal catarrh attacked almost one-fourth of the population and especially children up to 5 years old. The disease was caused by sewage leaking from a broken drain into water supply reservoir. No specific bacterium could be detected; but probably infection of some kind and not intoxication, was cause of epidemic.—*Manz.*

Feed Water Purification by Chemical Coagulation. RUDOLF DÖRING. Die Waerme, 56: 2, 25, January, 1933. Mine drainage water with high content of humic matter (40 to 50 p.p.m. $KMnO_4$), could not by treatment with soda-ash and sodium hydroxide be softened below hardness of from 1.75 to 2.92 grains per gallon and foamed excessively in boiler. Addition of 7.3 grains per gallon of magnesium sulphate with suitable quantities of soda-ash and sodium hydroxide reduced organic matter to from 20 to 30 p.p.m. $KMnO_4$ and hardness to from 0.17 to 0.29 grains per gallon; after two years of experience, foaming and priming were eliminated.—*Manz.*

The Determination of Dissolved Oxygen in Presence of Sulfite. L. W. HAASE. Zeitschr. für analytische Chemie, 90: 7–8, 241, 1932. In determination by WINKLER method of oxygen in hot water, treated with sulfite to absorb oxygen, low values are obtained, because of reduction of liberated iodine by sulfite. The elimination of sulfite by addition of iodine solution in excess, obtaining amount of excess from separate determination of sulfite, is only applicable at temperatures below 40°C.; at higher temperatures, additional iodine is liberated by reaction between NaOI and manganous hydroxide. In hot water samples above 40°C., excess iodine is best eliminated by thiosulfate and reaction between tetrathionate and manganous acid avoided by rapid working. To sample add first 1 cc. 0.1 N iodine, then 1 cc. 0.1 N thiosulphate, then, finally, the usual reagents; after cooling, titrate with either 0.01 N iodine, or 0.01 N thiosulphate, as case may be, to end-point. The somewhat troublesome calculation is explained by examples.—*Manz.*

Nomograph for Rapid Calculation of Sulfate-Carbonate Ratios. ROBERT T. SHEEN. Ind. Eng. Chem., Anal. Ed., 5: 4, 277–8, 1933. Given, in p.p.m., or in g.p.g., sulfate content as SO_4 and alkalinity, corresponding sodium sulfate to sodium carbonate ratio can be read directly.—*Selma Gottlieb.*

Handling of Distilled Water in Aluminum. H. V. CHURCHILL. Ind. Eng. Chem., Anal. Ed., 5: 4, 264–6, 1933. Distilled water from aluminum system contained 0.40 to 0.81 p.p.m. of total solids and 0.0047 to 0.012 p.p.m. of aluminum. Two samples from systems using tinned copper, block tin, and glass contained 1.9 and 12.3 p.p.m. of total solids and more aluminum than samples from aluminum system. Spectrographic analysis showed that residues come largely from raw water. Aluminum can be used for stills, condensers, and storage. Design and assembly of system are discussed and illustrated.—*Selma Gottlieb.*

Determination of Small Amounts of Manganese in Salt Solutions. NORMAN ASHWELL CLARK. Ind. Eng. Chem., Anal. Ed., 5: 4, 241–3, 1933. Fifty to 100 cc. of dilute manganese solution boiled with 5 cc. of 85 percent phosphoric acid and 0.3 gm. of potassium periodate yielded permanganate solutions stable up to seven months stored in dark. Usually 0.001 mg. of manganese could be detected in 50 cc. Nessler tube, and steps of 0.001 mg. could be read. Determination was successful in dilute and concentrated solutions of ferric chloride, primary calcium phosphate, magnesium sulfate and potassium nitrate, both

singly and mixed. Blue color formed by manganese with benzidine could be stabilized as precipitate, or in solution, by addition of various salts when manganese concentration was around one p.p.m., but not at greater dilutions. This fading interferes with use of test for quantitative purposes.—*Selma Gottlieb.*

Sources of Error in the Use in Water Analysis of Fairchild's Method for Determination of Fluoride in Phosphate Rock. MARGARET D. FOSTER. Ind. Eng. Chem., Anal. Ed., 5: 4, 238, 1933. Sulfates and calcium and magnesium chlorides cause high readings, but results are usually high, even in absence of interfering elements. Error might be as great as amount of fluoride present and method does not seem well adapted to water analysis.—*Selma Gottlieb.*

Colorimetric Determination of Fuoride in Water Using Ferric Chloride. MARGARET D. FOSTER. Ind. Eng. Chem., Anal. Ed., 5: 4, 234–6, 1933. Additional details and some modifications are reported on method previously outlined. (See J. A. W. W. A., 25: 7, 1042, 1933.) If more than 2.5 mg. of sulfate and/or 5.0 mg. of chloride are present, more than usual 0.375 mg. of iron per 50 cc. of sample must be added to compensate for iron by them withdrawn from reaction with thiocyanate. Curves are given from which required excess of iron can be read off. Residual iron is matched in Schreiner colorimeter, either against standards containing known amounts of iron, or, against standards containing constant amount of iron and varying known amounts of fluoride. If sample contains more than 2500 p.p.m. of sulfate, or 5000 p.p.m. of chloride, similar amounts of these ions should be added to standards, and 0.75 mg. of iron used throughout. Range of method is from 0.025 to 0.45 mg. of fluoride in 50 cc. sample.—*Selma Gottlieb.*

Determinations of Fluorides in Illinois Waters. C. S. BORUFF and G. B. ABBOTT. Ind. Eng. Chem., Anal. Ed., 5: 4, 236–8, 1933. Various methods for determination of small amounts of fluoride are discussed. Method of WILLARD and WINTER was adapted for use in water analysis. Volume of sample containing at least 0.2 mg. of fluoride is made alkaline to phenolphthalein and concentrated to 50 cc. in distilling flask. Some silica, or glass beads, 20 cc. of either concentrated sulfuric acid, or 60 percent perchloric acid, and enough water to cause boiling at 110°C. are added. From 50 to 150 cc. of distillate are collected, temperature being held at 130–140°C. by addition of water. Distillate is made alkaline with 0.2 normal sodium hydroxide, concentrated to 20 cc., and nearly neutralized with 0.2 normal hydrochloric acid; six drops of indicator are added, followed by dilute acid until color of indicator just disappears. (For less than 0.5 mg. of fluoride, indicator is solution of one gram of sodium alizarin sulfonate in 250 cc. of ethyl alcohol. For more than 0.5 mg., three parts of this solution are freshly mixed with two parts of a solution containing one gram of zirconium nitrate in 250 cc. of water.) Equal volume of neutral alcohol is added and solution titrated to faint pink with 0.01 to 0.02 normal thorium nitrate solution, which has been standardized against 0.02 normal lithium or sodium fluoride. Various Illinois ground and surface waters were examined. One p.p.m., or more, of fluoride was found in samples

from six communities in which mottled enamel had been reported.—*Selma Gottlieb.*

Correcting Trouble with Customers' Services. H. W. NIEMEYER and J. A. BRUHN. The American City, 48: 1, 50–53, January, 1933. Inadequate service will almost always result in complaints and, if not corrected, in loss of public good-will. It is caused either by inadequate pressure in mains, or else by defects in service line, or in interior piping. Indianapolis Water Company's method of running down complaints is described. Need for intelligent foresight on part of architects and builders to insure adequate interior piping is stressed.—*Arthur P. Miller.*

Meter Registration and Water Revenue: a Preliminary Study. H. W. GRISWOLD and W. A. GENTNER. The American City, 48: 1, 58–62, January, 1933. Under-registration by old meters means loss of income. Meter requirements and testing methods in force in Metropolitan District of Hartford, Connecticut, are described and discussed. Necessity is stressed for regular testing of meters in service, and at same rates of flow which occur in practice; also for repair procedure which will insure replacement of defective parts before excessive under-registration develops. Meter should always be of the proper size.—*Arthur P. Miller.*

Mountain Water for an Industrial City. THEO. REED KENDALL. The American City, 48: 2, 44–45, February, 1933. Kingsport, Tennessee, depends mainly upon a mountain supply impounded in 200,000,000-gallon reservoir. During times of heavy draft, river water is also used. Filtration plant, of usual design, pumping equipment, and river intake are described in some detail.—*Arthur P. Miller.*

Eight Years' Experience with Water Mains. W. H. WARING. The American City, 48: 2, 50–52, February, 1933. Based on experiences with water distribution system of Dallas, Texas, comprising 450 miles of pipe of various sizes, author discusses sizes of trenches; methods of pipe laying; location of gate-valves, air-release valves, and blow-offs; jointing materials; backfilling; and repair and maintenance.—*Arthur P. Miller.*

A Water-Supply Project Involving Pumped Storage. ANON. The American City, 48: 2, 60–62, February, 1933. Wilmington, Delaware, now pumps water from Brandywine Creek, during periods of high flow, over intervening ridge into a new 2,000,000,000-gallon reservoir behind Hoopes Dam. Water when needed, is returned through same force main to Porter Reservoir, from which it can either be drawn to slow sand filtration plant, or released into Brandywine Creek, to flow to rapid sand plant. Hoopes Dam is 900 feet long and 135 feet high, and depth of impounded water is 100 feet. Gate house, built integral with dam, contains draw-off gates at three elevations. Reservoir site and pumping station at dam are described.—*Arthur P. Miller.*

Colloidal Properties of Boiler Feed Water. O. E. Blincow. Jour. Inst. Brew., **37**: 603, 1931. Magnesium and calcium salts in water can be precipitated by addition of a colloid, in such condition that they will not form scale. Neither sodium nor caustic alkali is required; but suitable substances may be added together with colloid, to neutralize acidity and combine with dissolved oxygen.—*R. DeL. French.*

NEW BOOKS

Papers Presented at the Pennsylvania Water Works Operators' Association, State College, Pa., June 20–22, 1932. 122 pages. **Experience in Chlorinating a Gravity Water Supply at Scottdale, Pa.** F. W. Buck. 10–12. Chlorine was applied in 20-inch gravity main against back-pressure of 30 pounds per square inch by direct feed chlorinators. Normal flow in 1930 ranged from 200,000 to 800,000 gallons per day. Chlorine dose was 0.9 p.p.m. Appearance of leak led to investigation, which disclosed groove in top of pipe, slightly off center, 34 inches long, and at almost same distance from diffusers. The groove was shaped like an elongated bubble, with extreme width, circumferentially, of 10 inches and tapering towards either end. Trouble was attributed to formation of gas pocket during six hours of minimum velocity (one-tenth foot per second), when velocity at top of pipe would be negligible. To obviate recurrence of trouble, vacuum type solution-feed chlorinator operated by duplicate hydraulic pumps was installed. **Clarification by Coagulation without Filtration.** C. E. Burlingame. 13–16. Collecting reservoir at Berwick, Pa., was converted into a settling basin by withdrawal of water at surface level. Coagulant dosage was automatically applied with home-made apparatus. Treatment varied with variations in turbidity, alkalinity, and stream-flow. Dosages ranged from 0.3 grains per gallon of sodium aluminate with 0.75 grains of alum to 0.65 grains of sodium aluminate with 1.25 grains of alum. Sodium aluminate is advantageously applied mixed with 76° flake caustic soda in proportions of about 4 to 1. **Chlorine-Ammonia Treatment.** J. C. DeGroot. 16–18. After applying ammonia in conjunction with chlorine, at Northampton, Pa., tastes and odors were eliminated and water became extremely palatable. Chlorine residual was maintained in distribution reservoirs and system without taste, aftergrowths in distribution system were eliminated, and total bacterial counts materially reduced. **Experience with Chlorine-Ammonia Treatment.** J. G. Dell. 19. Ammonia and chlorine dosages caused odor and taste to disappear at Huntingdon, Pa. **Experience with Continuous Use of Activated Carbon in Taste Prevention.** Emerson Foster. 20–21. At Apollo, Pa., activated carbon has been used to reduce swampy, grassy taste and odor from filter effluent. Carbon is brought into suspension in 1800-gallon steel tank equipped with home-made agitators. No decrease in length of filter runs has resulted. **Coagulation Troubles.** Thomas Jones. 21–22. At Susquehanna, Pa., faulty floc formation with its disturbing influence in the filters and difficulty at times of high turbidity in attaining zero turbidity in filtered water are experienced. Notwithstanding trial of many corrective expedients, such as increasing alum dosage, adding lime, varying speed of mixing, and altering method of adding chemicals, problems have not yet been

fully solved. **Correction of Acidity.** E. O. HORNER. 23–24. Spoil piles deposited from coal strippings on watershed caused water at Shenandoah, Pa., to become corrosive. Tests showed acidity to be due to oxidation of sulphur compounds, and that little or no carbon dioxide was present. Caustic soda treatment was accomplished with good results by means of iron barrel, provided with a small cock, which allowed solution to drip into a pipe line. **The Cause and Cure of Red Water at Eagles Mere, Pa.** R. D. KEHRER. 24–26. Extreme purity of the water creates difficulties. It attacks pipe, becoming red and hardly fit to use. Iron-content increases from 0.10 p.p.m. at reservoir to 0.80 p.p.m. at a dead end in distribution system. Aëration and treatment with excess soda ash have improved situation. Customers who installed brass pipes have found that after twelve years use they will crush upon unscrewing. Plumbers are now using copper pipe. **Copper Sulphate and Fish.** WALTER STOCKBINE. 26–27. Treating water of Lake Ontelaunee, at Reading, Pa., with 0.36 p.p.m. copper sulphate, to kill *Melosira*, also killed many fish, owing to uneven distribution of chemical. Later treatment with 0.40 p.p.m. did not kill fish. Author is still uncertain as to what dose of copper sulphate would kill fish in this lake. **Displacement of Filter Gravel.** E. B. WAGNER. 28. Displacement of gravel over the manifold at Downington, Pa., was corrected by installing two steel plates 15 inches high, one on each side of manifold, forming trough. **Experiences with the Ammonia-Chlorine Process of Water Sterilization.** R. W. WOODRING. 28–29. Ammonia and chlorine are applied at Bethlehem, Pa., in ratio of 1:3, to overcome phenolic tastes. **The Elements of Water Bacteriology and the Reasons for their Application.** JOHN J. SHANK. 32–42. Bacteria, smallest living plants known, may be either (1) spherical, known as cocci, (2) rod-shaped, known as bacilli, or (3) cork-screw shaped, known as spirilla. Most bacteria of significance to water-works men thrive best at temperature of 37.5°C. (blood heat) and are grown in laboratories on culture media. Intestinal tract of man and of lower animals is normal habitat of many germs capable of causing dangerous diseases. There is no definite test for rapidly identifying typhoid bacteria, but colon group of organisms can be readily detected. Presence of *B. coli* group means presence of sewage. Three bacterial counts are of importance: (1) total count on standard agar at 37.5°C., giving indication of most of harmful organisms; (2) total count on gelatin at 20°C., useful index in pollutional studies; and (3) acid-producing colonies, presumptive evidence of the coli-aërogenes group. **Taste and Odor Control with Activated Carbon.** B. F. JOHNSON. 43–52. Treatment with from 3.5 to 7.0 pounds per m.g. of chlorine at New Castle, Pa., did not remove faint musty to woody taste, nor did applications of ammonia and chlorine in different ratios eliminate after tastes in distribution system. Activated carbon was, however, effective. Carbon did not save any alum, nor was color removal more efficient; but algae growth on piping and on basin walls was retarded. Three conditions are necessary for best results: (1) thorough mix, to obtain uniform and complete distribution of carbon particles throughout water treated; (2) sufficient contact period before filtration; and (3) application at proper point in purification process. Conclusions reached by the author are (1) removal of abnormal tastes and odors is generally complete; (2) carbon, when properly applied, has not interfered with filter

plant operations and has proved economical; (3) with exception of mild, but bitter, straw-like taste, all objectionable tastes have been removed; (4) treatment appeals to public mind because of its simplicity; and (5) its use has been controlled by the concentrate tests described. **The Use of Bleaching Clay in Water Purification.** EDWARD M. SLOCUM. 53–64. Two characteristics of adsorbent clays are cheapness and, being natural materials, inertness to chemical reagents. Unpleasant taste is nearly always bound up with odor, and bleaching clay is efficient in removing them when they come from oils. Odors arise either from gases, or from liquids, or solids, that have appreciable vapor pressure. Bleaching clay adsorbs odoriferous oils and solids, but not gases. Odor is removed by removing the substance causing it from the water. Experiments show that small traces of phenol can be eliminated and excess chlorine reduced by using clay. A heavy, rapid-settling, floc is formed when bleaching clay is used with aluminum sulphate. Author records removal of sulphuric acid and of color, more effective sterilization, and putrefaction reduction. Cost varies from seven to ten cents per million gallons. **The Use of Absorbing Clay for Removing Taste- and Odor-Producing Substances from Water.** RENNIE I. DODD. 65–67. Absorbent clay has been used at Chester, Pa., as one step in process of water purification. Writer believes that clay absorbs most of the highly hydrolysed oily substances, phenols, etc., and that aëration removes gases and the more volatile oils. Prechlorination oxidizes organic matter and kills taste- and odor-producing organisms. Coagulation, settling, and filtration become in this case finishing operations. Clay dosage has ranged from 0.1 to 0.6 grains per gallon, averaging 0.3 g.p.g. **Filter Sand and Gravel.** R. F. ABEL. 68–73. Filter sand must be composed of hard particles of high silica content, low in organic matter, and free from either long splinters, or flat scaly particles. Not over 15 percent of sand is suitable for filters. Sand for this purpose is commercially prepared by hydraulic process closely simulating backwashing operation in a filter bed, which is described. **The Cause, Prevention, and Elimination of Mud Ball Formation in Rapid Sand Filters.** EDWARD S. HOPKINS. 74–82. Sand size is important factor controlling mud deposit in filter beds: Sand of less than 0.4 mm. diameter is undesirable. As the top few inches of a filter removes the greatest amount of suspended material, it should be considered as the effective part. Where extended side wall cracks appear, excessive shrinkage has been caused by compacting of dirty sand grains. Releasing of pressure in filters causes adhering masses to fall into cracks, resulting in clogged area. Author advocates initial wash velocity which will only slightly expand top portion of bed. After cleaning this section, follow with maximum rate to expand the bed. Sand rise under given pressure of wash water is controlled by temperature changes; it is less in summer than in winter. This factor, together with increased thickness of sand grain coating explains appearance of mud deposits in summer. Caustic soda solution applied at the rate of one pound per square foot of bed, allowed to stand for about three days with periodic raking, and followed by washing will clean the bed. Various mechanical methods have also been suggested for cleaning the beds. **The Sterilizing Effect of Acid Waters.** LEWIS V. CARPENTER and EDMOND T. ROETMAN. 83–90. The conclusions reached by the authors are: (1) acidity determinations should be standardized

both as to technique and as to indicator; (2) acidity is very costly to water works in many respects; (3) period of contact of two hours between acid water and sewage is sufficient to destroy most of bacteria; (4) ten percent of mine water added to sewage will remove approximately 95 percent of the bacteria; (5) pH of 3.0 is optimum for growth of new strain of bacteria; and (6) bacterial count decreases with pH value. **Leakage Survey at Reading, Pa.** A. R. O'Reilly. 91–97. After metering entire system in 1926, unaccounted-for water amounted to 48 percent. Continuous leakage survey has since then been maintained. Combined cost of survey and repairs over period 1926–1931 has totalled $52,169.28; while value of water saved over period 1927–1931 has amounted to $1,881,525. In 1931, unaccounted-for water had been reduced to 24.5 percent. Two leak patrolmen cover 160 miles of piping every three weeks. Equipment used is metal rod and earphone. **Water Bearing Strata.** George H. Ashley. Pp. 98–101. The author describes the geological conditions affecting the occurrence of ground waters in Pennsylvania. **Water for Industrial Purposes.** A. S. Behrman. 102–109. Water used in manufacture of ice must be free from dissolved and from suspended matter, such as bicarbonates of calcium and magnesium, and iron. Zeolite process is not satisfactory for this purpose. Color is objectionable. Neutralization of residual alkalinity after lime treatment is desirable. Principal requirement for laundry and textile industries is freedom from iron, calcium, and magnesium. In soft drink industry, water must be clear and free from iron and objectionable taste. Taste is got rid of by pressure activated carbon purifier. Boiler water must be as free as possible from dissolved and from suspended solids: ratio of carbonate to sulphate must be kept within certain limits to prevent caustic embrittlement: it must be substantially free of oxygen to avoid corrosion.—*John F. Pierce.*

Annual Report of the Bureau of Sanitary Engineering, Maryland State Department of Health, 1932. Abel Wolman. 18 pp. Detailed report of Bureau's many activities in fields of water supply, sewage disposal and treatment, stream pollution, industrial waste treatment, oyster surveys, etc. Typhoid death rate, 3.0 per 100,000 was lowest ever recorded in history of state. Additional studies were made of corrosion in water distribution systems: review of all investigations made on this problem confirms conclusion that reduction in dissolved oxygen is indicative of active corrosion. Lime treatment after filtration has been adopted at several plants as corrective measure. Owing to reduced manufacturing activities, industrial waste pollution was less troublesome than in previous years. Milk plants were chief offenders. Measures adopted to combat pollution from that source are outlined. Findings and recommendations of Water Resources Commission of Maryland, which completed its investigations in 1932, are included.—*R. E. Thompson.*

Fifty-second Annual Report of the Department of Health, State of New York, for the year ending December 31, 1931. Thomas Parran, Jr., Commissioner. 327 pp. **Report of the Commissioner of Health: Sanitation.** P. 19. For third successive year there was not a single outbreak of typhoid fever in State which could be attributed to use of a public water supply. This has been due, in

large part, to better supervision of supplies and to fact that use of seriously polluted streams as sources of water supply is gradually being eliminated. Definite step to stop the pollution of Lake Erie and of Niagara River in vicinity of Buffalo was taken, when Governor ROOSEVELT notified officials of Buffalo and several other cities to appear at a hearing, and directed each to submit plans for sewage treatment. The Tri-State Treaty Commission, composed of representatives from N. Y., N. J., and Conn., was organized, following legislative enactments, to draw up compact for prevention and eradication of contamination and pollution of waters between these states and a committee on research and engineering prepared a report, recommending minimum standards of purity in each zone and in treaty area. In co-operation with N. Y. State Conference of Mayors, the division of sanitation conducted short schools for superintendents and operators of water works and sewage treatment plants. **Division of Sanitation.** C. A. HOLMQUIST, Director. p. 233. **Water Shortages.** Drought which seriously affected public water supplies during 1930 extended well into 1931. April was first month since June, 1930, that average precipitation for State was above normal. During this period of 9 months, aggregate deficiency amounted to nearly 9 inches. Water shortages, necessitating use of emergency or auxiliary supplies, were experienced at 25 places during 1931. **Development of New Supplies.** As result of decision of Supreme Court of U. S., it became possible for City of New York to begin development of its proposed supply from Delaware watershed. City was allowed to divert 440 m.g.d. on condition, among others, that sewage from Port Jervis be treated so as to remove 85 percent of organic matter and 90 percent of *B. coli* originally present. Impounding reservoirs will be developed on Neversink River and on east branch of Delaware River. It is estimated that tunnels, control works, and other parts of complete development will cost over $272,000,000. **Examination of Plans for Water Supply Projects.** Since June, 1931, all plans for new or additional water supply projects, which are required by law to be submitted to Water Power and Control Commission, have been sent by that Commission to State Department of Health for approval of sanitary features and of water purification processes. Plans for 45 water supply projects were accordingly passed upon during 1931. **Water Treatment.** General supervision is maintained over all municipal water filtration plants in State. At end of 1931, 118 such plants were in operation. Eight new filtration plants were constructed or put into operation during the year, namely, those at Albany, Attica, Catskill, Lockport, Madrid, Orchard Park, Ossining, and West Point. First practical application of liquid chlorine to public water supply in the U. S. was made in November 1912, at plant of Western N. Y. Water Co., at Niagara Falls. By 1915, there were some 25 such installations and, at close of 1931, more than 272 in regular operation. Apparatus for the application of ammonia to water supplies was installed at 15 places during 1931. **Outbreaks of Waterborne Disease.** During period from April 15 to May 1, 1931, there was an outbreak of about 2,000 cases of gastro-enteritis in villages of East Rochester, Pittsford, and Penfield, and in towns of Irondequoit, Greece, and Brighton, as well as in certain parts of city of Rochester. Although cause of this outbreak remains obscure, it bore the earmarks of waterborne epidemic. **Orders Issued by Commissioner of Health.** Village

of Camden was required to install modern chlorination plant for effective purification of its water supply. Village of Goshen was ordered to provide additional public water supply and to improve present supply by installation of efficient water purification works. Village of Gouverneur was required to install modern water filtration plant for effective purification of water from Oswegatchie river. Village of Phoenix was ordered to secure public water supply of safe sanitary quality. **Special Investigation of Fire-Pump Chlorinators.** There are in State 69 cross-connections between public water supply and industrial fire supply systems, where fire supplies are equipped with fire-pump chlorinators. Additional protection against pollution of the public supplies through cross-connections is provided by double check-valve installations. During April and May, 68 of fire-pump chlorinator installations were inspected. At time of inspection, 18 chlorinators, or 26.5 percent, were inoperative. In no case were both valves of a set found leaking, although 101 sets were inspected. **Stream Pollution by Milk Waste.** At Franklinville, during June, milk was dumped into public sewer system, interfering with municipal sewage treatment plant and causing serious pollution and killing of fish in Ischua creek above the intake of Olean water supply. Water-works officials at latter place were warned to maintain careful supervision over operation of filtration plant during this period.—*G. C. Houser.*

Standard Methods for the Examination of Drinking Water. Verein Deutscher Chemiker. Verlag Chemie, G. M. B. H., Berlin. Appearing in parts. First part (16 pp.) gives exact details for sampling, determinations to be made, with sections upon temperature measurement, and odor and taste, turbidity, and color determinations, with 21 illustrations of sampling apparatus, thermometers, nephelometers, and colorimeters. Second part (18 pp.) gives full working details for determination of residue on evaporation, loss on ignition, suspended matter, reaction, hydrogen-ion concentration (colorimetrically, electrometrically, and by ratio of free to bicarbonate carbon dioxide), phenolphthalein and methyl-orange alkalinity, acidity, calcite-aggressive carbon dixoide, and rust-promoting carbon dioxide. Several methods are given for rapid works tests, as well as more elaborate laboratory processes. Tables are given of pH values with indicators, with Sörensen's solutions, and by free carbon dioxide to bicarbonate carbon dioxide ratios; tables are also given of relation between phenolphthalein and methyl orange alkalinities when hydroxide, carbonate, and bicarbonate are present, and of aggressive carbon dioxide. Illustrations (11) of apparatus are given and both parts are invaluable to water chemists.—*W. G. Carey.*

The Water Engineer's Handbook and Directory, 1933. 348 pp. 8s. 6d. Published by Water and Water Engineering, 30 Furnival Street, Holborn, London, England. Contains particulars of water undertakings in British Empire, giving names of chief officers, area and source of supply, character, treatment and distribution of water, developments in progress and in prospect, water rates, statistics of population and of areas supplied, consumption, storage capacity, length of mains and rateable value, with alphabetical list of engineers and authorities to which attached. Summary of water supply in

1932 deals with typhoid epidemics, purification by ozone, lead water pipes, etc. Article on engineering geology as applied to water works deals with classification of water resources, and surface and subterranean water supply. Article on water treatment summarizes self-purification of rivers, sedimentation and storage, aëration, filtration, and water softening. Rainfall in 1932 is dealt with, as well as statute law of 1932 as affecting water undertakings, water law, and legal cases. Sections on hydraulic data and formulae include tables, rainfall, storage and compensation, aqueducts, pipes and distribution, purification of water, and prime movers and pumps. Many references are made to American practice.—*W. G. Carey.*

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29 West 39th Street, New York, N. Y.

Additions to Membership List During Year 1933

ACTIVE MEMBERS

Joined

ACIOLY DE SA, PAULO, Engr., Prof. of Hyds., Escola Polytechnica Rua Bulhoes De Carvalho N. 163, Copacabana, Rio de Janeiro, Brazil .... Jan. 1, 1934
ALB, H. S., Supt., Bureau of Water, City Hall, Altoona, Pa .... Jan. 1, 1933
ALEXANDER, CARL, Tubize Chatillon Corp., Rome, Ga .... Apr. 1, 1933
ARMSBY, SIDNEY P., Asst. Sales Manager, California Chemical Corp., 1717 Mills Tower, San Francisco, Calif .... Jul. 1, 1933
ARNOLD, GERALD E., Water Purification Engineer, San Francisco Water Department, Millbrae, Calif .... Oct. 1, 1933
ARNOLD, WILLIAM L., Auditor, San Gabriel Valley Water Co., 15 So. Garfield Ave., Alhambra, Calif .... Jul. 1, 1933
AVERETT, MILTON D., Sales Manager, The Georgia Gravel Co., Columbus, Ga .... Jul. 1, 1933
BARRY, MAJOR DAVID, Engineer, National Defence, Canadian Bldg., Ottawa, Ont., Canada .... Jan. 1, 1934
BIEHLHAUSEN, LOUIS A., Electrician, Menominee Indian Mills, Neopit, Wis .... Jan. 1, 1933
BIRD, L. C., Messrs. Phipps & Bird, Richmond, Va .... Oct. 1, 1933
BLACK, HAYSE H., State Technician on E.C.W., 121 State Capitol Bldg., Springfield, Ill .... Oct. 1, 1933
BRADY, M. J., Sanitary Chemist, Dept. of Water & Power, 4771 Mendota Ave., Los Angeles, Calif .... Jan. 1, 1933
BRATTON, JOHN C., Asst. Treas., Consolidated Water Co., 712 Washington St., Utica, N. Y .... Jan. 1, 1933
BREDEHOFT, HENRY E., Engr. in Charge, Plant Operation, Los Angeles Dept. of Water & Power, 410 Ducommun St., Los Angeles, Calif .... Jul. 1, 1933
BRIGGS, HENRY M., Asst. Secretary, Hollister Water Co., Hollister, Calif .... Jul. 1, 1933
BROS, FRANK J., Supt., Bureau of Water, 5145 Cermak Road, Cicero, Ill .... Jan. 1, 1933
BRUNNER, JOHN F., Vice Pres. & Gen. Mgr., Middletown & Royalton Water Co., 308 Commonwealth Trust Bldg., Harrisburg, Pa .... Oct. 1, 1933
BUCCOWICH, JR., PAUL, Supt., Light & Water Dept., Ely, Minn .... Jan. 1, 1933
CALLAHAN, T. G., City Manager, P. O. Box 202, Clayton, New Mexico .... Jan. 1, 1934
CAMPBELL, H. A., Supt. of Public Activities, Cornwall, Ont., Canada .... Jan. 1, 1933
CAMPBELL, JOHN W., Superintendent, Water Works, Ridgetown, Ont., Canada .... Jan. 1, 1934
CASHIN, WILLIAM D., Supt., Water Works Department, 317 Broadway, Kingston, N. Y .... Jul. 1, 1933
CHARLES, E. D., Supt. of Public Works, Julesburg, Colo .... Oct. 1, 1933
CHASE, GEORGE E., Manager, Bowmanville Public Utilities, Bowmanville, Ont., Canada .... Jul. 1, 1933
CLAUS, A. E., Superintendent Water Works, Beamsville, Ont., Canada .... Jan. 1, 1934
CODY, J. P., Asst. Treas., Ohio Water Service Co., 235 State St., Struthers, O .... Jan. 1, 1933
COGSWELL, W. F., State Health Officer, Helena, Mont .... Jan. 1, 1933
COOPER, M. B., Asst. City Engineer, Augusta, Ga .... Jan. 1, 1933
CRAIG, GEORGE L., Pres., Brownsville Water Co., 808 Columbia Bldg., Pittsburgh, Pa .... Oct. 1, 1933
CRIST, MARION L., Assoc. Engr., Burns-McDonnell-Smith Eng. Co., 461 S. Le Doux Road, Los Angeles, Calif .... Jan. 1, 1933
DAILY, C. M., Water Commissioner, 312 City Hall, St. Louis, Mo .... Jul. 1, 1933
DANIELS, PAUL I., Land Agent, East Bay Municipal Utility Dist., 512-16th St., Oakland, Calif .... Jan. 1, 1933
DAVIS, WALTER S., 686 Myrtle Ave., Albany, N. Y .... Apr. 1, 1933
DAWES, E. A., Dawes Construction Supply Co., Thomasville, Ga .... Jan. 1, 1933
DENTON, FRANK, Supt. of Water Works, Salem, Ill .... Jan. 1, 1933
DESLAURIERS, ALFRED JOSEPH, Civil Engineer, 18th Avenue, Lachine, Que., Canada .... Jan. 1, 1934
DOOLEY, R. J., Superintendent, Board of Water & Light Commission, Le Roy, N. Y .... Jan. 1, 1933
DOTO, JOSEPH A., Member, Board of Water Commissioners, 2213 Tatnall St., Wilmington, Del .... Oct. 1, 1933

Joined

Driggs, Edwin L., Office Engineer, East Bay Municipal Utility Dist., 512-16th St., Oakland, Calif. .... Jan. 1, 1933

Ebert, Raymond E., Chemist, Municipal Sewage Treatment Works, Winston-Salem, N. C. .... Oct. 1, 1933

English, James A., City Engineer & Superintendent of Water Works, Salisbury, N. C. .... Oct. 1, 1933

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Gama, Jose, Civil Engineer, Ave. Chapultepec 168, Mexico, D. F., Mexico .... Jan. 1, 1933

Garcia, Raul Ressano, Chief Engineer, Common Council of Cascaes, R. Dos Navegantes 65, Cascaes, Portugal .... Jan. 1, 1933

Gohier, Ernest, C. E., Consulting Engineer, 10 E. St. James St., Montreal, Que., Canada .... Jan. 1, 1934

Golden, A. T., Water Treatment Plant Operator, Los Angeles Dept. of Water & Power, 327 W. 1 St., Wilmington, Calif. .... Apr. 1, 1933

Gottlieb, Miss Selma, Chemist, Water Laboratory, State Board of Health, Lawrence, Kans. .... Apr. 1, 1933

Goudelock, Paul M., Chemist, City Water Works, 76 W. Washington St., Gainesville, Ga. .... Jul. 1, 1933

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Gray, Harold Farnsworth, Sanitary & Hydraulic Engineer, 2540 Benvenue St., Berkeley, Calif. .... Jul. 1, 1933

Green, Carl E., State Sanitary Engineer, 816 Oregon Bldg., Portland, Ore. .... Jul. 1, 1933

Green, Fred, Senior Chemist, Water Treatment Section, London & North Eastern Railway, Stratford, London, E. 15, England .... Oct. 1, 1933

Griswold, Lawrence J., Engr., Consolidated Water Co., 712 Washington St., Utica, N. Y. .... Jan. 1, 1933

Grosz, George, Mgr. Public Utilities Commission, Town Hall, Waterloo, Ont., Canada .... Jan. 1, 1933

Grunsky, Jr., C. E., Gen. Supt., East Bay Municipal Utility Dist., 512-16th St., Oakland, Calif. .... Jul. 1, 1933

Gullans, Oscar, Senior Chemist, Experimental Filtration Plant, 9432 Rhodes Ave., Chicago, Ill. .... Apr. 1, 1933

Gutteridge, Wesley W., Civil Engineer, 8975 215th Place, Queens Village, L. I., N. Y. .... Jan. 1, 1933

Haas, S. G. Frank, Technical Engineer, Sewerage & Water Board, New Orleans, La. .... Jul. 1, 1933

Hall, L. Standish, Chief Hydrographer, East Bay Municipal Utility Dist., 512-16th St., Oakland, Calif. .... Jul. 1, 1933

Haney, W. R., Manager, Ashland Division, Wisconsin Hydro Electric Co., 220 E. Second St., Ashland, Wis. .... Oct. 1, 1933

Hanks, C. W., Supt., Water Works Construction, 1720 California St., Denver, Colo. .... Jul. 1, 1933

Hansell, Wm. A., Asst. Chief of Construction, City Hall, Atlanta, Ga. .... Oct. 1, 1933

Harris, John P., 205 W. Wacker Drive, Suite 1306, Chicago, Ill. .... Jan. 1, 1934

Hausmann, A. R., Asst. Pacific Coast Manager, U. S. Pipe & Foundry Co., 681 Market St., San Francisco, Calif. .... Jul. 1, 1933

Hayes, Harry, Jr., Civil Engr., Field Engineering Investigations, Dept. of Water & Power, Box 240 Arcade Annex, Los Angeles, Calif. .... Jan. 1, 1933

Heddell, Douglas, Plant Construction Engineer, Los Angeles Dept. of Water & Power, 2243 Brier Ave., Los Angeles, Calif. .... Jul. 1, 1933

Heeney, Carden Thomas, Engineer, 344 Fifth Ave., Ottawa, Ont., Canada .... Jan. 1, 1933

Hellstrom, Carl I., Superintendent, Water & Light Dept., Geneva, Ill. .... Jan. 1, 1933

Hill, Alfred H., Vice Pres., Francis Hankin & Co., Ltd., 2028 Union Ave., Montreal, Que., Canada .... Jan. 1, 1933

Hubbard, Edward, Civil Engr., Dept. of Water & Power, 207 South Broadway, Los Angeles, Calif. .... Jan. 1, 1933

Hudson, Jr., H. E., Junior Sanitary Engineer, Experimental Filtration Plant, 6843 Oglesby Ave., Chicago, Ill. .... Jul. 1, 1933

Hunter, G. A., Supt. of General Construction, East Bay Municipal Utility Dist., 512-16th St., Oakland, Calif. .... Jan. 1, 1933

Hutchinson, M. C., Managing Director, Victaulic Co. of Canada, Ltd., 200 Bay St., Toronto, Ont., Canada .... Jan. 1, 1933

Imbt, William C., Asst. Geologist, 305 Ceramics Bldg., Urbana, Ill. .... Jan. 1, 1933

Irwin, Gifford M., City Engineer, City Hall, Victoria, B. C., Canada .... Jan. 1, 1933

Jessup, B. L., State Board of Health, Raleigh, N. C. .... Jan. 1, 1934

Johnson, L. E., Engineer, Box 1404, Wilson, N. C. .... Oct. 1, 1933

Jones, James E., Asst. Engr., Los Angeles Dept. of Water & Power, Box 240 Arcade Annex, Los Angeles, Calif. .... Jul. 1, 1933

Joined

Jordan, William H., Asst. Supt. of Grounds & Chief San. Patrolman, East Bay Municipal Utility Dist., 512-16th St., Oakland, Calif. ... Jan. 1, 1933

Kahn, James M., Sales Engineer, International Filter Co., 105 Rumson Road, Atlanta, Ga. ... Jan. 1, 1934

Kennedy, Robert C., Chief Designing Engineer, East Bay Municipal Utility Dist., 512-16th St., Oakland, Calif. ... Jan. 1, 1933

Ker, Merle F., Engineer, Township of Stamford, Niagara Falls, Ont., Canada ... Jan. 1, 1934

Kiker, Jr., John E., Engr., Water Purification, L'Hydraulique-Asie, 81 Rue Richaud, Saigon, Indo-China ... Jan. 1, 1933

Kimball, John H., Acct.-Sect., East Bay Municipal Utility Dist., 512-16th St., Oakland, Calif. ... Jan. 1, 1933

Lang, O. H., Consulting Engineer, Moultrie, Ga. ... Jul. 1, 1933

Lonergan, Town Engineer, P. O. Box 395, Buckingham, Que., Canada ... Jan. 1, 1933

Long, John S., Supt. of Water, Tampa, Fla. ... Jul. 1, 1933

MacDonald, Geo. L., Asst. Engr., Wallace & Tiernan, Ltd., 278 Spadina Road, Toronto 12, Ont., Canada ... Jan. 1, 1933

Mace, O. E., Chief Chemist, Chesapeake & Ohio Ry. Co., Room 407, C. & O. Station, Huntington, W. Va. ... Jul. 1, 1933

Malcolm, William Lindsay, Professor of Municipal Engineering, Queens University, Kingston, Ont., Canada ... Jan. 1, 1934

Manbert, Cal R., Construction Engr., East Bay Municipal Utility Dist., 512-16th St., Oakland, Calif. ... Jul. 1, 1933

Manz, Hermann, Consulting Chemist, Sybelstr. 68, Berlin, Charlottenburg, Germany ... Jan. 1, 1933

Matheson, D. H., Chemist & Bacteriologist, Beach Filtration Plant, Box 86, R. R. 5, Hamilton, Ont., Canada ... Jan. 1, 1934

Mathews, F. Rockwell, Water Superintendent, Mount Kisco, N. Y. ... Jan. 1, 1934

May, Charles E., Supt. of Water Works & Public Property, City Hall, Meridian, Miss. ... Jan. 1, 1933

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A STREAM FLOW STUDY OF THE TOKYO WATER SUPPLY*

BY TOMIHISI IWASAKI

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When the author's association with the Tokyo Water Works was just beginning in 1924, the Kwanto district of Japan experienced a severe drought comparable to that of 1930–31 in the United States. Since that time, in his capacity as head of the supply division of the Tokyo Water Works, he has studied extensively the characteristics of the River Tama, from which Tokyo diverts its water, and has checked his methods with records of the Nunobiki watershed of the Kobe Water Supply, Japan, and the Pomeraug Basin in the United States. It was his hope to present an elaboration of this report at the World Engineering Congress held in Tokyo in 1929, but the press of other work delayed the completion of the studies and the preparation of the notes.

This paper is in the nature of a summary of a part of such studies and will attempt to illustrate the author's application of precipitation—run off relationships to the River Tama. The River Tama is a fairly mountainous stream with a watershed area of 156.7 square miles and is the source of the Tokyo water supply.

* Revised and reduced in space by Charles Stein—*Editor*.

A knowledge of the relationships existing between rain-fall and run-off serves not only as a general check on stream flow measurements, but also as one of the few instruments for the interpolation of

TABLE 1

Comparison of run-off computations for January

(All data are given in inches)

YEAR	MEASURED JANUARY RUN-OFF	RAINFALL, JANUARY	RAINFALL, NOVEMBER, DECEMBER AND JANUARY	CALCULATED, JANUARY RUN-OFF	RAINFALL, NOVEMBER AND DECEMBER	CALCULATED, JANUARY RUN-OFF	RAINFALL, NOVEMBER	CALCULATED, JANUARY RUN-OFF
1929	1.70	0.24	5.24	1.38	5.00	1.63	2.76	1.66
1928	1.35	3.50	7.76	1.75	4.25	1.55	2.18	1.59
1927	1.10	0.75	5.16	1.36	4.41	1.56	1.10	1.47
1926	1.85	1.26	8.98	1.97	7.72	1.91	3.78	1.77
1925	1.30	1.06	3.07	1.02	2.01	1.31	1.34	1.49
1924	1.74	0.24	8.27	1.83	8.03	1.94	6.14	2.05
1923	1.52	2.44	6.42	1.55	3.98	1.52	3.23	1.71
1922	1.71	1.97	4.53	1.27	2.56	1.37	0.51	1.40
1921	2.02	3.58	9.84	2.06	6.26	1.76	2.17	1.59
1920	2.46	3.19	11.97	2.39	8.78	2.02	6.22	2.06
1919	2.17	3.66	10.35	2.14	6.69	1.80	3.78	1.77
1918	1.65	0.55	3.11	1.06	2.56	1.37	2.48	1.63
1917	2.59	1.14	15.39	2.90	14.25	2.60	10.83	2.58
Average per-cent error.				14.7		12.4		12.7
Coefficient of correlation........		0.746	0.801		0.737		0.701	

Equations for run-off:

Using sum of November, December and January rainfall:

$$Y = 0.150\ P + 0.59 \text{ inch}$$

Using sum of November and December rainfall:

$$Y = 0.105\ P + 1.10 \text{ inches}$$

Using November rainfall:

$$Y = 0.115\ P + 1.34 \text{ inches}$$

missing and inadequate data, the forecasting of future stream flow and the anticipating of periods of drought. A proper means of forecasting stream flow will enable the mitigation of some of the effects of water supply droughts by early restrictions to consumptions.

It has been common practise to correlate stream flow in calendar periods with rainfall in identical periods in order to obtain run-off factors and monthly or seasonal rainfall-stream flow equations. The majority of such attempts lead to the conclusion that such relationships are too inconsistent to be of great value. The method takes no cognizance of the fact that the rainfall in one month will contribute to stream flow not only in that month but in succeeding months.

In arranging a method whereby stream flow can be more accurately anticipated, the first step was the investigation of the correlation between the run-off in any month and the rainfall in a series of months preceding and including the month under consideration. In other words, it was desired to determine the value of the rainfall in various combinations of months as an index to future stream flow.

Table 1 shows the rainfall and runoff of the River Tama for the month of January for thirteen years, together with various combinations of rainfall in preceding months. The computed yields have been obtained from the rainfall-runoff relations for each set of data. These equations for simplicity are cast in the form, $Y = mP + C$, wherein Y is monthly yield, P is monthly precipitation or the sum of the precipitations considered, and m and C are constants selected by trial or deduced by plotting the run-off against rainfall, and afterward adjusting the resultant curve to give the best correlation with the measured data.

Inspection of the table will reveal that the measured January stream flow varied between 1.0 and 2.59 inches per month while the rainfall varied between 0.24 and 3.66 inches and that the variations in rainfall are not synchronized with the variations in stream flow. There is a much more pronounced correlation between the total rainfall for November, December and January and the measured January stream flow. January is one of the worst winter months and its stream flow is subject to the erratic effects of snow storage, thaws and other climatic variations. Consequently the simple run-off variation using that month's precipitation alone is apt to be grossly misleading. Fair computed results, however, can be obtained by the method outlined above, as evidenced by table 1.

The coefficients of correlation in table 1 are an index of the agreement between the computed and the actually recorded data. They are obtained by determining the departure from the mean of each set of data, calculating the normal departures and determining the coefficient in the usual manner, thus:

$$\text{Normal variation of rainfall, } p = \frac{\Sigma\ (\text{departure of } P)^2}{n \text{ number of } P\text{'s}}$$

$$\text{Normal variation of run-off, } y = \frac{\Sigma\ (\text{departure of } Y)^2}{n \text{ number of } Y\text{'s}}$$

$$\text{Coefficient of correlation} = \frac{\Sigma\ [(\text{departure of } P) \times (\text{departure of } Y)]}{n \times p \times y}$$

Figure 1 shows the actual recorded run-off of the River Tama through the winter or normal low flow period for six years, together

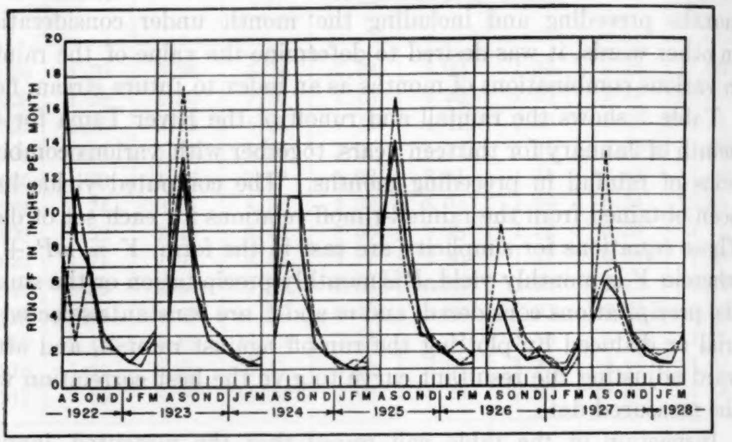


FIG. 1. COMPARISON OF ACTUAL RUNOFF AND RUNOFF CALCULATED BY CORRECTING MONTHLY RAINFALL—RIVER TAMA AT KORI, JAPAN

Key:

——— Measured runoff.

– – – Runoff calculated from precipitation in two preceding months and the current month.

—·—· Runoff calculated from precipitation in two preceding months.

with the calculated run-off as computed from the rainfall of the preceding two months and the current month, and also as computed for the two preceding months only. As illustrated, the method of calculating stream flow by determining the relationship between actual yield and the rainfall of a proper selection of influencing months gives computed yields that are in at least approximate agreement with those actually measured.

However, this method is based on general reasoning only and takes no account of the decreasing influence of any rainfall on stream

flow with the lapse of time. Thus, the November rainfall has a more marked influence on the December run-off than has the rainfall of September. A careful analysis of the hydrograph of a river can be made to determine the influence of particular quantities and times of rainfall on run-off in succeeding periods. Such an analysis will enable the apportionment of the part of individual precipitations contributed in months following.

GENERAL CHARACTERISTICS OF RUN-OFF

Early in 1929 the author approached this problem of the decreasing effect of any rainfall with the concept that the run-off attributable to a particular rainfall could be obtained by an application of the depletion or yielding curve of the stream. Under normal conditions following a rainfall and in the absence of further rainfall, stream flow decreases in accordance with self-evident principles. After the first rapid surface run-off, the preponderant flow consists of the least entrained ground water, this being followed in preponderance by the deeper ground water contribution which, as the ground water level drops, becomes ever lessened in magnitude. Even with succeeding precipitation to prevent a drop in ground water level, the ground water contribution attributable to any rainfall will always diminish due to depletion of the ground water remaining in storage from that particular rainfall, the depletion being replaced by the diluting water of succeeding rainfalls.

When rainfall on a watershed ceases, the rate of stream flow becomes a function of the hydraulic slope of the ground water. The continuing flow of the stream is accompanied by a lowering of the water table, the rate of lowering depending upon the rate of stream flow. The higher the rate of discharge, the more rapid will be the rate of depletion. It will follow that the rate of depletion of stream flow is a function of the magnitude of stream flow. A natural corollary is that at times of equal flow, barring interference by further rainfall or climatic inequalities, the rate of yielding will be equal.

However, stream flow studies are concerned with a long series of depletions and replenishments and in the average basin long continuing and complete depletion is a rarity. If, at two points on the hydrograph of an average stream, it is considered that rainfall ceases and that the stream flow diminishes in accordance with the laws of depletion, the difference in the stream flow resulting from these two hypothetical conditions would be, substantially, the run-off contributed by the intervening precipitation.

Reference to figure 2 will illustrate the problem. Period 1 is assumed to start with the occurrence of rainfall P_1. Were rainfall P_1 not to occur, the rate of stream flow would follow the lowest of the depletion curves on the diagram. However, since P_1 actually occurs, it causes the rate of discharge to rise above the first depletion curve. The end of Period 1 is marked by the occurrence of a second rainfall, P_2. Had there not been a rainfall P_2, the stream flow would have followed the second depletion curve. The area between the two depletion curves constituted by the incremental areas, dY_11, dY_21, dY_31, etc., represents the increase in stream flow caused by rainfall P_1.

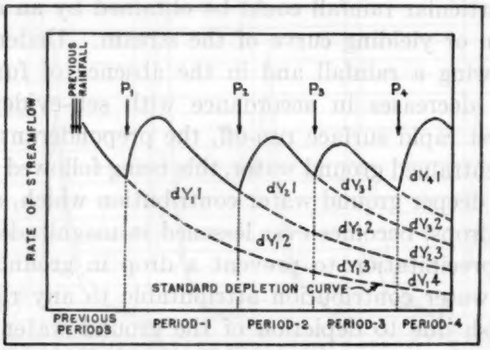


FIG. 2. ILLUSTRATION OF THE INCREMENTS OF RUNOFF ATTRIBUTABLE TO RAINFALL

This concept opens the way for a simple approach to the problem of properly segregating and classifying the various parts of a hydrograph and relating the precipitation in any period with the stream flow resulting strictly from that precipitation.

The depletion curve for stream flow in drought periods, one week or more after precipitation ceases, may be analyzed fundamentally by applying the principles of ground water movement. There are several works on this subject, the most notable being that of Darcy derived for flow through a permeable column:

$$v = \frac{kh}{1}$$

wherein "v" is the velocity through the permeable column, "h" is the difference in head, and "k" is a constant depending on the characteristics of the material and other variables.

A yielding curve for the River Tama is obtained by an application of Darcy's formula for stream flow values between 0.85 and 1.25 cubic feet per second per square mile. In its final form it is:

$$Q = 4.6272\ e^{-0.082793\ t}$$

Q = discharge in C.F.S. per square mile; e = the Naperian base, 2.718281; t = the time in days following the rainfall.

The yielding curve may be obtained empirically by locating on the hydrograph periods of no rainfall and determining the most appropriate form of curve to apply to the actual numerical record

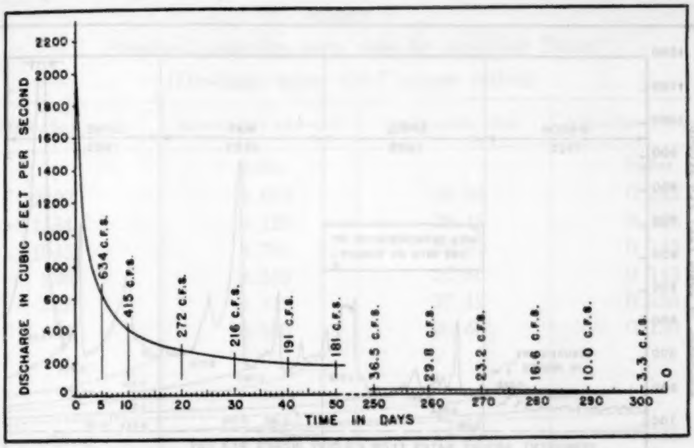


FIG. 3. STANDARD DEFLECTION CURVE OF THE RIVER TAMA AT KOBI, JAPAN

Drainage area, 156.7 square miles

of stream flow. The curve may be an exponential function such as: $Q = ae^{-ct}$, or $Q = ae^{-ct}(1 - e^{bt})^n$, etc.; or the general shape may dictate a hyperbolic function such as:

$$Q = \frac{a}{t + b} + c$$

Q being the discharge and t being the time in days following the rainfall.

However, in these studies it is not intended to develop an exact function for the depletion curve. The author uses a representative curve for the River Tama approximated from hydrographs of the river and calls it the standard depletion curve of the basin. This curve is shown on figure 3.

The shape of the depletion curve is determined by plotting the hydrograph, and fitting the depletion curve to the tail part of the flood flow, assuming a practical point of final zero ground water flow. With a knowledge of the general shape of the depletion curve, the author believes that the errors introduced by this approximate method are not serious.

Having derived the standard depletion curve, the author divides the hydrograph into periods beginning at the end of every month and at each point of low flow. The area of the hydrograph is then divided by drawing a standard depletion curve through each point of

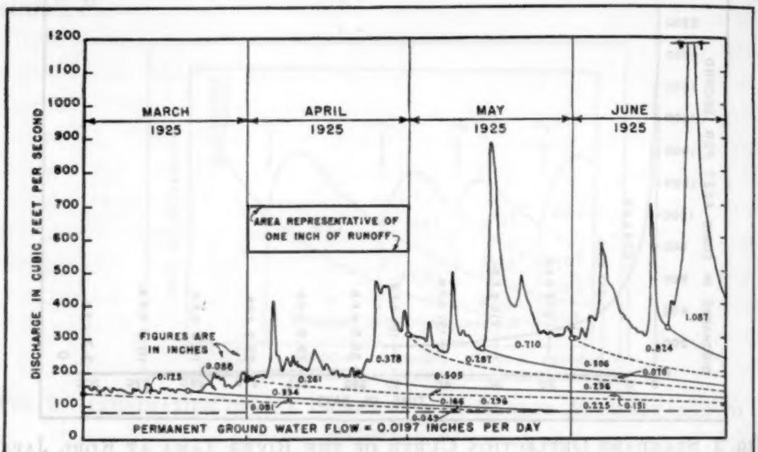


FIG. 4. DIVIDED HYDROGRAPH OF RIVER TAMA AT KORI, JAPAN

Drainage area, 156.7 square miles

division. A portion of the divided hydrograph of the River Tama is shown in figure 4, wherein an assumption of constant deep ground water flow has been made.

In order to arrive at the contribution to the stream flow effected by rainfall in any division, it is necessary merely to determine the area between the two depletion curves, starting at the beginning and the end of the division. Although this may appear to be a tedious procedure involving planimetering of a great many areas or the computation of sections of functional curves, the process can be greatly simplified by computing for various rates of flow the areas remaining beneath the depletion curve. The results, arranged in tabular form,

can be applied directly to the discharges indicated by the divided hydrograph. An example from the table for the standard Tama depletion curve is shown in table 2.

In the use of table 2, to find the volume of run-off represented by any section of the depletion curve, it is necessary to determine the rate of flow represented by the beginning and the end of the section of the depletion curve, interpolate the remaining bounded area in inches of run-off for each point and by subtracting obtain the entire representative area beneath the section of the curve. To find the

TABLE 2

Standard depletion curve data for the River Tama

(Drainage area—156.7 square miles)

DISCHARGE, C.F.S.	REMAINING RUN-OFF	DISCHARGE, C.F.S.	REMAINING RUN-OFF
	inches		*inches*
2322	9.679	29.85	0.163
1534	9.128	29.18	0.156
1045	8.765	29.52	0.149
829	8.516	27.86	0.143
713	8.319	27.19	0.136
634	8.150	26.53	0.130
......	.....	.....	.....
......	.....	.....	.....
......	.....	.....	.....
167.5	4.940	13.27	0.033
165.9	4.821	12.44	0.030
165.0	4.781	11.61	0.027
164.2	4.742	10.78	0.022
......	.....	.....	.....
......	.....	.....	.....

area between two curves, the computation is made for each and the difference obtained.

Thus far, there has been described a method whereby the hydrograph can be analyzed to obtain the approximate true run-off resulting from any precipitation. In the attempt to forecast run-off or to interpolate missing data, it is desirable to know the effect of the rainfall in any one period on the run-off of all succeeding periods. This information can be obtained by developing rainfall influence lines which indicate the percentage of any rainfall which is to be expected as run-off in any period following the rainfall. A general

illustration will suffice to explain the nature of the influence line and the method of its construction.

RAINFALL INFLUENCE LINES

Figure 2 represents for five periods a hydrograph consisting of the run-off from three rainfalls, P_1, P_2, and P_3 and, in addition, the receding run-off from previous rainfalls. The increment of run-off occurring in one period and attributable to one rainfall is denoted by dY, submarked and suffixed respectively to indicate the affecting rainfall and the period of its occurrence with reference to the time of the affecting rainfall. Thus, P_1 causes the increments of yield dY_11, dY_12 and dY_13 in the periods of 1, 2 and 3 respectively. Similarly,

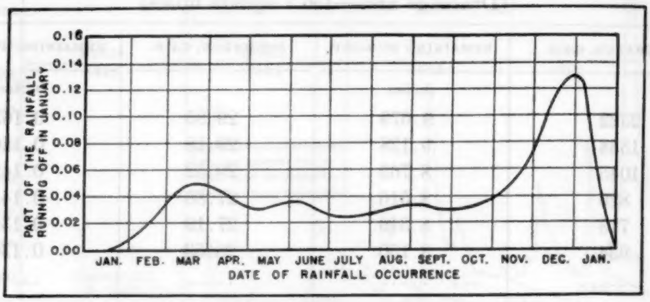


FIG. 5. RUNOFF INFLUENCE LIFE FOR JANUARY

River Tama at Kori, Japan

P_2 occurring in period 2, causes the yields dY_21, dY_22 and dY_23 in the periods 2, 3 and 4 respectively.

It can be seen that the total yield caused by rainfall P_1 is $dY_11 + dY_12 + dY_13 + \ldots$ etc., or $\Sigma dY_1 = Y_1$. Similarly, the total yield attributable to rainfall P_2 is $\Sigma dY_2 = Y_2$.

The ratio between dY_11 and P_1 will give the fractional part of the rainfall P_1 which results in the period during which the rainfall occurs. Denoting this fraction with the symbol dK_11 and submarking and suffixing similar ratios for the other increments of yield in accordance with the scheme used for the dY's, it follows that the complete run-off ratio, K_1 is equal to:

$$\Sigma\, dK_1 = dK_11 + dK_12 + dK_13 + \ldots \text{ etc.} = \frac{Y_1}{P_1}$$

The determination of these incremental dK's for a sufficient number of periods will provide a practical instrument for investigating

the relative effect of any rainfall on the yield during succeeding periods. From the hydrograph, divided as heretofore illustrated, by the depletion curves, all the rainfalls affecting the stream flow in any month may be determined. If, for any month, say August, we compute the dK's of all rainfalls contributing to the August run-off and plot the magnitudes of the dK's in chronological position on a chart divided into months and days, the plotted points will give the trend of the influence of all rainfalls on the yield in August. The run-off influence curve for the River Tama at Kori for the month of January is shown in figure 5. To use this curve, the depth and date of each rainfall are obtained from meteorological records and

TABLE 3

Run-off for January, 1918, computed by the influence line method

RAIN DATE	DEPTH OF RAINFALL	dK	CALCULATED DEPTH OF RUN-OFF
	inches		*inches*
March 2, 1917	2.95	0.038	0.112
March 22, 1917	4.73	0.050	0.237
April 3, 1917	3.70	0.030	0.111
June 2, 1917	7.64	0.035	0.267
July 6, 1917	5.69	0.024	0.137
July 30, 1917	6.48	0.028	0.181
September 8, 1917	3.80	0.034	0.129
September 20, 1917	6.52	0.030	0.196
November 2, 1917	2.97	0.040	0.119

Total calculated depth of run-off, inches — 1.489
Actual measured run-off inches, — 1.65

the percentage of the rainfall appearing as stream flow in January is obtained by referring to the curve. Similar curves are calculated for each month of the year. For convenience, especially where the influence curve is approximately flat, the rainfall over periods may be bulked. An illustration of the procedure is afforded by table 3, wherein the run-off for January, 1918 is calculated.

Figure 6 shows graphically a comparison of the actual stream flow and stream flow as calculated by the use of rainfall influence lines. Inspection of the chart will show that the agreement between actual and computed stream flow is especially close during the low flow or drought period.

Perfect agreement between rainfall as recorded and stream flow as measured is, of course, never possible, since meteorological stations are never sufficiently numerous to give recordings truly representative of entire water sheds. Stream flow measurements are themselves subject to considerable error, diurnal fluctuations, stage-discharge and recorder errors being present at all times. Winter

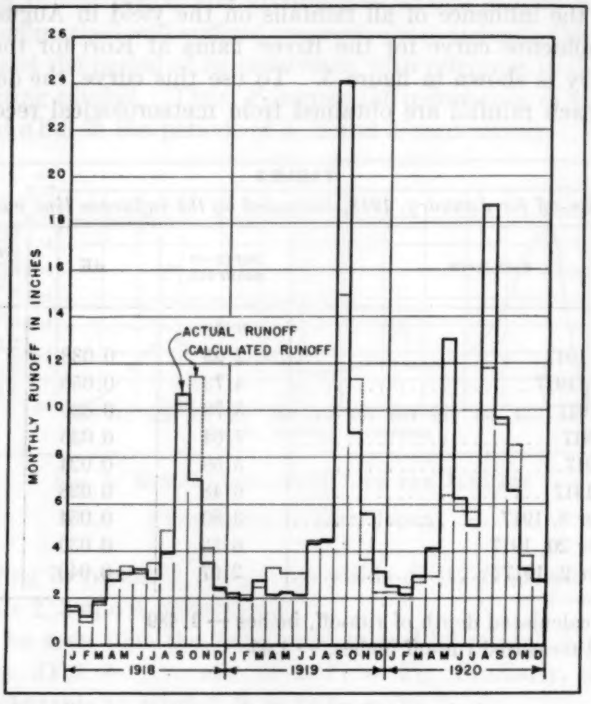


FIG. 6. COMPARISON OF ACTUAL RUNOFF AND RUNOFF CALCULATED FROM RAINFALL INFLUENCE LINE METHOD

River Tama at Kori, Japan

precipitation records are never true precipitations as long as continual adjustments are not made for snow storage and meltage. Temperature variations and other climatic conditions, by affecting evaporation losses and the moisture demands of vegetation, introduce significant inconsistencies in rainfall-stream flow relationships. In consideration of these several effects the agreement between the actual run-off and the calculated run-off of the River Tama as shown

on figure 6 can be considered, for the low flow months at least, as being within the range of error incident to the measurement of basic data and the indeterminate nature of the bulk of rainfall losses.

SUMMARY

Stream flow in any period is not the result of rainfall in the period alone, but is affected also by rainfall in preceding periods. That rainfall-stream flow relationships should be based on preceding rainfall as well as on precipitation in the period considered is a natural corollary of this fact.

Since the rainfall in preceding periods constitutes at least a part of the stream flow in any period, the rainfall in preceding periods can be used as an approximate index for the forecasting of stream flow.

The time depletion relationship can be applied to stream flow data to determine more accurately the stream flow resulting solely from the precipitation in a given period.

Stream flow can be synthesized provided sufficient data are available to develop the influence of rainfall on succeeding periods of run-off, as outlined in the body of this report.

Further study of the methods outlined, especially the character of the hypothetical depletion curve in normal and wet periods, will be of definite and practical value.

REPORT ON BUREAU OF STANDARDS SOIL CORROSION AND PIPE COATING INVESTIGATION[1]

There follows an outline of the scope, progress and some results of the studies of soil corrosion and protective coatings for buried pipe lines in progress for the past ten years at the Bureau of Standards, under the direction of Mr. K. H. Logan, Chief, Underground Corrosion Section. This information was gathered at the Bureau on July 6 to 8, 1933, during previous visits, and from published and unpublished reports. The principal published reports and papers are abstracted in three Bureau of Standards Letter Circulars, LC 328, LC 329, LC 330. Some of the interpretations, marked (Wo), are my own.

CONTENTS OF THIS REPORT

This report is arranged under the following major topics:

- Soil corrosion studies
  - Materials under test
  - Burial
  - Results to date
    - Bare ferrous pipe materials
    - Ferrous pipe with metallic coatings
    - Service pipe materials
    - Other non-ferrous materials
- Studies of protective coatings
- Bearing on coatings for inside of water pipes
- Practical application of the data now available
- Final report on soil corrosion
- Future work—New Corrosion Resistant Materials and Non-Bituminous Coatings
- Acknowledgment

SOIL CORROSION STUDIES

Materials under test

The following are the primary materials under test. Data on these are now generally available up to 8 or 10 years, and will be

[1] A report made to the American Water Works Association and the Sectional Committee on Specifications for Cast Iron Pipe, whose representative the author was at the Bureau of Standards conference, July 7, 1933, on the draft report on Soil Corrosion Studies, 1932.

available up to 10 or 12 years when the remaining specimens are taken up in 1934 preliminary to the preparation of the final report.

Group A. *Ferrous pipe* of pure open hearth iron, hand puddled wrought iron, bessemer steel, scale free bessemer steel, open hearth steel, open hearth steel with 0.2 percent copper, deLavaud cast, pit cast from northern ore, pit cast from southern ore, and high silicon cast iron. Also lead, as cable sheath but applicable to lead pipe, of two compositions and some other materials (12 years burial in 1934).

Group B. *Supplementary ferrous pipe material.* Pit cast, southern ore, as cast, also machined; deLavaud as cast, also machined; monocast; high tensile cast; and cast steel and malleable cast-iron fittings (10 years burial in 1934).

Group C. *Ferrous pipe and pipe materials with metallic protective coatings* including: galvanized pipe of pure open hearth iron, wrought iron and copper bearing open hearth steel, and galvanized sheets of the same base metals and of bessemer steel including two gages and a wide range in weight of zinc; lead coated steel pipe; calorized pipe made by both the dry and the wet process; and sherardized and galvanized wrought-iron bolts and nuts (10 years' burial in 1934).

Group D. *Service pipe and fittings materials.* Four brass or bronze alloys of 75 percent or higher copper content, such as used in corporation and curb cocks, each made up in separate specimens with lead, galvanized, and brass (Muntz metal) pipe to show the effect of dissimilar metals (10 years burial in 1934). These alloys were in the form of large, unfinished cast caps, and are to be distinguished from certain small, finished caps, presumably of Muntz metal, on the other ends of the Muntz metal nipples.

Group E. *Material available for service pipe, without bi-metallic contact.* Copper and brass (Muntz metal) pipe, forged brass elbows and copper-aluminum and nickel brass (in the form of rod) (8 years burial in 1934). (Note lead without bi-metallic contact in Group A.)

Group F. *Miscellaneous materials* submitted by the Bureau of Mines, repeating some of the above materials in sheet or plate form and adding zinc, other brass and bronze, aluminum, commercial and with 1.5 per cent Mn, and duralumin (10 years burial in 1934).

BURIAL

Groups A, D and the galvanized and lead-coated pipes of Group C were buried at 47 locations representing about 40 soil series. A special group of 3 of the rolled and 2 of the cast materials in Group A was

buried in a variety of soil types under each of several representative soil series, making 25 additional locations. The other materials were buried in a smaller number of representative soils.

Results to date

Separate sets of specimens have been removed from each soil, cleaned, and loss of weight and depth of pits determined, at 2-year intervals, except that in 1932 the specimens were removed from only the more corrosive half of the soils. The results prior to the 1932 report, which are not essentially changed by that report, are abstracted in Letter Circulars 328 and 329. Very briefly the high spots to date are as follows:

Bare ferrous pipe materials (Groups A and B)

1. The type and severity of the corrosion of the ordinary ferrous materials, Groups A and B (except high silicon iron), are determined by the soil much more than by the material.

2. No one of the rolled ferrous pipe materials in Group A has shown outstanding superiority in all soils to the end of 10 years. Averaging the tenth year results in the 23 most corrosive soils the differences do not greatly exceed the differences between two lots of the same material. A material low in loss of weight may be high in pitting and vice versa.

3. The cast irons in Group A, except high silicon iron, average somewhat more loss of weight and depth of pitting than the rolled materials, but generally not in proportion to the greater thickness of the walls of commercial pipe. The corrosion residues in cast iron, unlike those of wrought iron and steel, are generally strong, except it is stated, where corrosion is rapid as in case of corrosion forced by an impressed electric current of considerable current density.

4. In certain soils a particular ferrous material, which may be either rolled or cast, shows a consistent superiority in loss of weight or rate of pitting, or both, throughout the 10 years, but in many soils there is no important and consistent difference, either throughout the test or at the end of 10 years. It is obvious that significant superiority of any one of these materials can only be shown for the particular soil in question, or a closely analogous soil, and by considering the loss of weight and the pitting data for the entire period of the test. Results at any single age may be misleading (Wo.).

5. Substantially all of the rolled materials and many of the cast

materials of Group A after 10 years in the more corrosive 23 of the 47 soils and of Group B after 8 years in a few soils, had suffered what I would consider commercially important corrosion. In the worst soils some of both the rolled and the cast specimens were perforated[2] (Wo.).

6. The pitting data are a direct measure of resistance to failure by perforation. The loss-of-weight data indicate the *average* weakening of the pipe wall, but in many cases greatly underindicate the local weakening along one side or element which in a working pipe under pressure would favor bursting (Wo.). In a working pipe line this concentration of corrosion along or near an element is generally on the bottom.

7. *In general* the annual increase in loss of weight and depth of pits in a given soil diminishes with time. Pitting diminishes relatively rapidly in the first 4 years, more slowly from 4 to 10 years. There are a few soils in which the data appear to show a nearly constant or even an increasing rate of pitting, but the final specimens at 12 years may modify this apparent trend.

8. It is probable that in working pipe lines in the same soils there would be materially deeper pits, and materially earlier perforation of the same thickness of metal, than indicated by these small ferrous specimens (1½-inches to 6-inches diameter, 6 inches long). Some of the reasons for this conclusion are that (*a*) the larger the area the greater the chance of an extra deep pit; (*b*) in a pipe of larger diameter the difference in kind and compactness of soil, oxygen supply and moisture between the top and the bottom of the pipe are greater than with small specimens, these differences tending to form a galvanic cell; (*c*) a pipe line passing through two different soils, even miles apart, may also form a galvanic cell, corrosion being concentrated where the current leaves the pipe.

9. The high silicon cast iron after 10 years showed small to negligible loss of weight and no pitting in most of the 23 most corrosive soils. The metal is not, however, immune to the action of all soils as pitting occurred in two soils and important loss of weight in one, 0.25 oz. per square foot per year in tidal marsh (Wo.).

10. Corrosion of high tensile cast iron, malleable cast iron and cast steel, so far as the very limited data yet available show, is not notably different from that of pit cast pipe.

[2] Some were perforated at much earlier ages. It should be noted the soil is in contact with both outside and inside of the pipe, and early perforation may result from the intersection of inside and outside pits.

Ferrous pipe with metallic coatings (group C)

The ferrous pipe specimens with metallic coatings were specially made and coated all over. The following conclusions appear justified—

11. Lead coating showed deeper pitting than hot dip galvanizing in all of the 14 soils from which both were removed after 8 years (Wo.).

12. Calorizing shows no advantage in pitting over hot dip galvanizing *in excess of the probable experimental error* in any of the 5 soils from which both materials were removed after 8 years, whether done by the wet or by the dry process; in 3 cases by one process, in 5 cases by the other it shows deeper pits than galvanizing (Wo.).

13. On galvanized material the weight of zinc coating varies materially from place to place and from the nominal weight. Coatings nominally of 2 oz. per square foot varied from 1.62 to 2.82 oz. per square foot on different specimens.

14. Galvanizing has afforded very substantial protection of ferrous pipe in the 14 corrosive soils compared after 8 years.

15. There is no significant difference in the underground corrosion resistance of galvanizing on pipes or sheets of different base metals which can be attributed to the base metals.

16. In general the heavier the zinc coating the less the loss of weight and pitting but the data are not entirely consistent.

Service pipe materials

In the composite specimens made up of such high copper alloys as are used in cocks, etc., coupled to lead, galvanized and brass pipes respectively:

17. The four alloys of 75 percent or higher copper content (for analyses see Technologic Paper 368, Table 16) all showed excellent corrosion resistance after 8 years burial in all soils but tidal marsh.

18. In general there was no significant difference in the resistance of these four alloys. In certain soils the 75 percent copper alloy showed coppery discolorations suggesting surface dezincification (Wo.). In tidal marsh the higher copper alloys appeared to have suffered more than the lower copper alloys or even than 60:40 brass (Wo.). The only serious loss of weight, 0.39 oz. per sq. ft. per year for the average of the 4 alloys attached to the 3 kinds of nipples, occurred in tidal marsh.

19. In 5 of the 22 corrosive soils, including muck and peat, these alloys experienced considerably more loss of weight when attached to lead than when attached to brass or galvanized iron.

20. In 2 of these 22 corrosive soils the loss of weight of the attached lead nipples exceeded, and in several others approached the loss of weight of bare rolled ferrous pipes in the same soils. All of the lead nipples showed greater rates of loss of weight than unattached lead in the same soils.

21. The brass (Muntz metal, about 60 percent Cu, 40 percent Zn) nipples in all soils but tidal marsh showed much greater rates of loss of weight than the attached higher-copper-alloy caps. In most of the 22 corrosive soils it showed copper colored discoloration, the discolored areas being weak, easily cut with a knife and crumbling to powder when cut (Wo.). In 2 soils the threads were so weakened that they stripped when disconnecting for weighting. In many the dezincification had markedly weakened the nipples (Wo.). In general the apparent weakening of the brass nipples was much greater than indicated by the loss of weight (Wo.). Unattached Muntz metal has shown much the same deterioration in some soils, but it is the writer's impression that the amount of comparable data is as yet too small to warrant any conclusion as to whether the corrosion of the connected nipples was accelerated by galvanic action (Wo.). In tidal marsh the Muntz metal nipples were very little affected, much less than the connected higher copper alloys (Wo.).

22. The small brass caps, finished all over, which closed the ends of the Muntz metal nipples opposite the large alloy caps, and which are presumed to be of the same composition as the nipples, showed noticeably less discoloration and softening (Wo.). The reason is not known (Wo.).

23. The galvanized nipples closed with galvanized caps, connected to the special copper alloys, showed more loss of weight in all soils than the galvanized pipe specimens without bi-metallic contact, markedly more in all soils but one. The nipples connected to the copper alloy caps had unprotected threads, whereas the unconnected galvanized pipe specimens were galvanized all over; but, since these latter specimens showed little definite evidence of an increased rate of corrosion after the zinc was penetrated exposing bare iron, it seems probable that the higher rates of corrosion of the galvanized nipples connected to the copper alloy caps was due to galvanic action rather than to exposed threads. The preceding conclusions of this paragraph are the writer's and differ from those of the Draft Report (Wo.). In several soils the corrosion of these galvanized nipples was severe,[3] and in two soils they were destroyed after 8 years burial.

[3] To the point of puncture.

24. These composite specimens probably do not fairly represent working service pipes in that in these specimens the cathodic areas of the higher copper alloys representing corporation and curb cocks were substantially equal to the anodic areas of the pipe material. In working service pipe lines in similar soils it seems probable that corrosion of the pipe material would generally be less than in these tests (Wo.). This is more fully discussed in Research Paper 359, p. 589.

Other non-ferrous materials

25. Lead (Group A, in the form of cable sheath) has not been immune to all soils but shows serious loss of weight and pitting only in a very few soils. Antimony lead shows at least no greater corrosion resistance than commercial lead (Wo.).

26. Copper pipe (6 to 8 years in only 8 of the more corrosive soils) generally shows about one tenth the loss of weight of bare rolled ferrous pipes in the same soil; in muck and tidal marsh, however, the loss of weight approximates $\frac{1}{5}$ and $\frac{2}{5}$ respectively of that of unprotected rolled ferrous metals (after 8 years), though the rate of pitting of the copper is a small fraction of that of the ferrous materials. Only in tidal marsh of the few soils in this comparison does brass show convincing superiority to copper. Bronze, 90 Cu. 10 Zn. behaved much like copper (5 soils). Only in tidal marsh (of 5 soils) do the data suggest the use of aluminum or its alloys in place of copper but here both brass and lead show but slight corrosion. There are no data on copper and aluminum in peat (entire paragraph—Wo.).

STUDIES OF PROTECTIVE COATINGS

For some years past the Bureau of Standards has been conducting a coöperative investigation of protective coatings for underground pipe lines participated in by the American Petroleum Institute, Dr. Gordon N. Scott, Research Associate, the American Gas Association, Dr. Scott Ewing, Research Associate, manufacturers of coatings and the operators of oil and gas pipe lines. It is reasonable to say that this coöperative research has done more during the past 3 or 4 years to inject engineering principles into the selection, design, construction, application, inspection and testing of organic pipe line coatings that has been accomplished in the entire previous history of the industry.

Some results of the work to date are indicated in Bureau of Standards letter circular LC-330. Results of more recent work have been

published in the progress reports on the A. P. I. Pipe Coating Tests and of the Sub-committee on Pipe Coatings and Corrosion of the A. G. A.

Without attempting to abstract these reports, the following may be noted:

The work includes laboratory studies of coating materials and coatings, exposure tests of small coated specimens (3-inch steel pipes 2 feet long) in corrosive soils, in many cases in parallel with similar coatings on working pipe lines, also inspections of older working pipe lines having known coatings, and the correlation of all the data with one another and with the characteristics of the soil.

The A. G. A. in 1929 and early 1930 buried short pipes coated with 42 different coatings in 14 selected soils. The A. P. I. in 1931 applied 19 coatings to working pipe lines in 16 soils and in these soils buried bare short pipes for control and 46 kinds of coating.

Inspections of all the above and of other working pipe lines are made from time to time by standard methods which have been developed and which largely eliminate the personal equation. These include visual inspection, pinhole pattern and conductance tests before removing the coating, and pit measurements. The results have been published for the examination of the A. G. A. specimens up to 2½ years and for the A. P. I. coatings on working pipe lines up to 2 years.

While much more time is needed for final results, based on the published reports certain conclusions can now be drawn:

A. Thin paint films and unreinforced soft coatings are of very doubtful value, in any soil.

B. There is marked increase in effectiveness of coating with increased thickness up to about 0.1-inch.

C. The asphalt emulsions are probably too soft to resist penetration by soil pressure.

D. Most firm or hard soils tend to puncture the coating by the pressure either of the pipe on the bottom of the trench or of stones, clods or lumps of hard, dry clay in the backfill. The stresses due to the shrinkage and swelling of certain wet clays also tend to rupture the coating.

E. Soil stresses are, therefore, one of the most destructive agencies affecting coatings on the outside of buried pipes. Where these soil stresses are to be anticipated, thick, hard enamels or reinforced or shielded coatings appear to be required.

F. The A. G. A. Committee on Pipe Coatings and Corrosion in its 1933 report makes specific though tentative recommendations with respect to the types of coatings suitable for different classes of soils.

Both the tests and field experience emphasize the importance of proper application. There is need for reliable tests to detect defects of application that they may be corrected before backfilling and such tests are being developed. It is a part of the program of the Underground Corrosion Section to develop and standardize tests for the identification of coating materials, for measuring those properties which determine the life of the coating and its effectiveness in protecting the underlying metal, and for detecting defects of application immediately after coating and before backfilling.

The objective of all this work is to enable the engineer to determine his coating requirements at any point, and to design, specify, test and inspect his materials and finished coating including the discovery and correction of defective application before backfilling, with something like the same precision and confidence with which he determines the pressures along his pipe line, designs, tests and inspects his material and pipe for strength, and tests his field joints for leakage before backfilling. This coöperative work heading up in the Bureau of Standards seems likely to measurably achieve this end.

BEARING ON COATINGS FOR THE INSIDE OF WATER PIPES

While this study of coatings has reference only to the protection of the outside of the pipe its results promise to be of the greatest value in the selection and use of organic coatings for the inside of water pipes. Corrosion in both places is an electro-chemical process affected by the resistivity of the coating, its permeability to water and chemical solutions, its resistance to decay, its permanent adhesion to the metal at all points, and its freedom from holidays and pinholes. Considering the vicissitudes of handling and laying the pipe and inspecting the finished line, mechanical strength of the coating, limited susceptibility to extremes of temperature, and ability to deflect with the pipe wall without cracking, are essential in both cases. The writer believes that all the field observations on the enumerated qualities, and all the tests for identification of materials and for measurement of these essential qualities will be directly applicable to protective coatings for the inside of water pipe lines.

PRACTICAL APPLICATION OF THE DATA NOW AVAILABLE

The soil corrosion tests heretofore described have been made in soils at 47 locations. Perhaps one third to half of these soils may be considered definitely corrosive in the sense of causing commercially important damage within a comparatively few years to ferrous pipe lines not protected by effective coatings (Wo.). These corrosive soils represent, however, a comparatively small part of the total land areas; over the greater part of the area of the country the soils are but slightly corrosive. While corrosive soils are most abundant and the economic problem most serious in certain parts of the South and West, limited areas of corrosive soil may occur in almost any locality. For example, although the North and East, including New York State, are in general regions of relatively non-corrosive soils, 6 of the 23 more corrosive of the 47 soils tested are represented in New York State, and of the three highly organic and highly corrosive soils muck, peat and salt marsh, one or another may occur in almost any state. Without investigation of the soil or prior experience with buried pipe lines no region can safely be considered immune. All of the discussion of this report deals, of course, with corrosion uninfluenced by stray current electrolysis.

The soils included in this study represent about 40 of the about 300 distinct soil series in the continental United States excluding Alaska. Correlation between the corrosive properties of the test soils and of the others is being worked out. Under each soil series there are a number of soil types, differing largely in texture. Much progress has been made in correlating the corrosiveness of soil types with that of the parent soil series. If not interrupted, all of this correlation should be finished in about 2 years. The following is the writer's understanding of the practical problem and the means now available for its solution.

The soils of the country being mainly non-corrosive or but slightly corrosive, but limited areas of highly corrosive soil being likely to occur in almost any region, the practical economic problem in designing any pipe line is:

(a) To determine the corrosiveness of the prevailing soil and its action on pipe coatings.

(b) If the prevailing soil is not generally so highly corrosive as to require uniform protective treatment throughout, to locate and delimit the corrosive areas.

(c) To select that combination of pipe material, wall thickness and

protective coating which promises the minimum overall cost, considering the probable useful life of the pipe as limited by other factors than soil corrosion, the damage caused by leaks and interruption of service, and the cost of replacement.

In outline the procedure, in the absence of experience with other pipe lines in the same territory, would be:

a. *Identification of the soil or soils.* The soil survey maps of the United States Department of Agriculture now afford this identification for the one half of the agricultural land for which these maps have been completed, including nearly the whole of certain states. Lacking these maps identification requires a soil survey for which advice from State or Federal departments of agriculture might be obtained.

b. *Comparison with the test soils.* On completion of the final report of the Bureau's Soil Corrosion Investigation all recognized soil types will, so far as possible, be rated for corrosiveness. With the soil identifications and this rating it will generally be evident whether further study and expert assistance are warranted or whether soil corrosion can be neglected. Pending this rating, for soils not included in the Bureau's tests, in the absence of soil identification, and in any case where the corrosiveness of the soil on any part of the line is in doubt, this should be supplemented by:

c. *Consideration of the drainage condition* along the line of the pipe, wet soils often being points of active corrosion.

d. *Determination of the corrosiveness of the actual soil at pipe line depth.* For this purpose there is no one test which is reliable in all places, but several methods of demonstrated merit, under appropriate conditions, are available, including rapid field tests of soil resistivity, and laboratory determinations of soil acidity and short-time loss of weight of steel discs in the suspected soil.

e. *Selection of the pipe materials,* wall thicknesses and/or coatings best adapted to the conditions found, in the light of the Bureau's tests in similar soils.

FINAL REPORT ON SOIL CORROSION

It is planned to remove the last specimens (except certain long time specimens) in each of the groups heretofore described from all of the soils in 1934, giving a 12-year test on most of the ferrous materials. If not interrupted, and with no serious reduction in funds and personnel, the final report should be finished in about 3 years.

With the data and methods to be described in this final report and

with the soil maps of the Department of Agriculture it will, I understand, be possible, among other things, to predetermine with reasonable accuracy: the corrosiveness of any recognized typical soil in the continental United States exclusive of Alaska, the probable depth of pitting of working pipe lines of any of the hereinbefore described materials in such soil for any time of exposure, the location and extent of especially corrosive "hot spots" requiring especial protection along the route of a projected pipe line, and similar matters.

FUTURE WORK—NEW CORROSION-RESISTANT MATERIALS AND NON-BITUMINOUS COATINGS

In response to a demand from representatives of the utilities for better pipe line materials and to requests from manufacturers for tests of new products, a new series of materials has been buried in 15 corrosive soils. This series consists of 24 ferrous materials, mostly forms of pipe, 13 non-ferrous pipe materials and 11 non-bituminous costings. A few metallic materials of both groups tested in the original series are repeated for purposes of control and special comparisons. Material has been provided to allow the removal of specimens at 2-year intervals up to 10 years. This new series is limited to corrosive soils since the ordinary materials show adequately long life in other soils.

It is also possible to leave in the ground for a longer test a set of specimens of the original series in 20 or more of the less corrosive soils, from which specimens will have been examined at 2, 4, 6, 8 and 12 years. This will give very conclusive information as to the change in rate of corrosion and pitting with time if their examination at a later date can be arranged for.

ACKNOWLEDGMENT

Acknowledgment is due to Mr. K. H. Logan, Chief, Underground Corrosion Section, for facilities for and assistance in examining the corrosion specimens, for making available many unpublished studies and reports, and for explaining many details. Acknowledgment should be made also of the coöperative work which has been done by the American Petroleum Institute, American Gas Association, The Cast Iron Pipe Research Association, all through Research Associates maintained at the Bureau, and the manufacturers of pipe materials and protective coatings; also of the assistance of many individual oil, water and gas companies in furnishing sites and labor for the

burial and removal of specimens, also of the work of many of the pipe line holding companies in developing and correlating methods of testing the corrosiveness of soil with the conditions found on working pipe lines. This whole study of underground corrosion and protective coatings has been a great coöperative undertaking which all heads up in, and is coördinated by, the Underground Corrosion Section of the Bureau of Standards. This work could hardly have been done by any other agency. If not deprived of adequate funds and personnel, or unduly restricted in the continuance of its coöperative activities, this work of the Underground Corrosion Section with its coöperating agencies promises to put the whole difficult problem of underground corrosion and protective coatings and the economics of the protection of buried pipe lines on a sound engineering basis. Unquestionably also the current and projected work on protective coatings, while planned with reference to the outside protection of pipe lines, will be of the greatest value in the identification, testing, selection and inspection of coatings for the inside of water pipe lines.

LEONARD P. WOOD.

ELECTRIFICATION OF THE BRILLIANT PUMPING STATION AT PITTSBURGH, PA.

By James H. Kennon

(Managing Engineer, Bureau of Water, Pittsburgh, Pa.)

The water system of Pittsburgh consists of four essential parts: the filtration plant with raw water pumping station and intake, the primary pumping stations with their reservoirs, the secondary pumping stations with their reservoirs, and the distribution system.

The two primary pumping stations are (1) Aspinwall Station, pumping to Lanpher Reservoir for supply to the North Side or the Old Town of Allegheny, the district North of the Allegheny River, and (2) Brilliant Station, pumping to Highland Reservoirs Nos. 1 and 2, for supply of the "Central" or peninsular part of the City and certain districts located South of the Monongahela River. Approximately 70 million gallons daily, or 60 percent of the average daily water used, is pumped by the Brilliant Pumping Station, and it is, therefore, considered the most important of the City's stations.

The old Brilliant Steam Station was placed in operation in 1879, pumping raw water from the Allegheny River up to 1907, when the filtration plant was completed; from that time it has received its supply of filtered water through two 72-inch concrete encased steel pipes across and under the Allegheny River, a distance of approximately 1500 feet. When the station was abandoned in 1932, its equipment consisted of four 12 and four 15 m.g.d. vertical, compound pumping engines and one 8 m.g.d. vertical, triple expansion pumping engine; also seven 520 h.p. water tube boilers as regular equipment, and two 350 h.p. water tube boilers, one 200 h.p. return tubular boiler and two 125 h.p. locomotive type boiler which were installed in 1930, as an emergency measure.

The four 12 m.g.d. units were installed in 1896 and had been in almost continuous operation since.

The necessity for radical improvements on the station was realized several years ago, as the age and condition of the plant not only made it extremely un-economical in operation, but also constituted a

real hazard in the reliability of the City's water system. After a preliminary survey, funds were reserved in 1926 for necessary improvements. Due to the importance of the project, however, it became necessary to make extensive studies of the most desirable course to be followed. Of the many different plans under consideration, the final choice was between (1) a new steam station in a new building with high pressure steam pumps, and (2) a new all-electric station. Any improvements of the old plant were considered out of the question on account of the extremely poor condition of the buildings and equipment. Another very important reason for the construction of an entirely new plant, on the available ground adjoining the old plant, was that the yard piping with its numerous check and gate valves and odd shape connections had been a constant source of trouble and expense, and from an operating standpoint it was considered essential to make a complete replacement with a layout much more simple and easier maintained.

The preliminary estimates indicated that the total annual cost (including fixed charges) of operating an electric station exceeded by about $36,000.00 the annual cost of a steam plant. The estimated first cost of an electric plant was, however, only $900,000.00 as against the cost of $1,730,000.00 for a steam plant. If the supply of money for financing all the needs of the Bureau of Water had been unlimited, the plan for a steam plant would probably have been adopted. The Pittsburgh Water Works, however, requires a considerable annual appropriation from bond funds for extension and rehabilitation of plant, averaging about one million dollars yearly. With the supply of money limited it was necessary to take into consideration the lower first cost of an electric plant, and applying the difference in construction cost to other purposes where a greater return in terms of revenue, service and dependability of supply could be obtained. As an instance, the return in revenue from the purchase and installation of water meters during the past years has been found to fully justify that policy. Furthermore, the greater simplicity, and ease of construction and operation of an electric plant as compared with a steam plant, were factors in the decision, as was also the fact that the electric plant would be less likely to reflect future increases in labor rates and coal cost than would the steam plant with a much larger operating force. An indirect advantage of an electric plant has been the very substantial decrease in supervision and maintenance engineering.

For the above reasons it was finally decided to construct an electrically operated pumping station, and this new station was placed in operation in May, 1932, about 21 months after the first contract, that for the pumping units, had been awarded. One of the six units of this contract was delivered in December, 1930, and was temporarily installed in the old steam plant, partly as an emergency measure and partly to test the reliability of this size and type of unit before the steam plant was abandoned and the City's water supply was made dependent on the new plant. We gained, during that period, some valuable experience, and consequently had some minor changes introduced in the set-up of the new pumping units, which enabled us to avoid troublesome shut-downs of the new station.

THE NEW ELECTRICALLY OPERATED STATION

The new building was designed in an entirely modern style, with all ornamentation eliminated, and presents a very attractive appearance. The exterior facing is Indiana limestone, and the roof is porous concrete slab covered with French shingle tile. The interior walls are faced with a cream colored ceramic glazed brick which is easily cleaned. Floors are red quarry tile. The building has the most modern conveniences for the operating force, and ample ventilation and lighting is provided to assure healthy and safe working conditions. The main pump room is lighted with eighteen 750-watt lamps and reflectors, suspended between the roof trusses, and the effect is an absolute absence of shadows on or around the pumping units; the intensity of lighting is indicated by 17-foot candles on the pump room floor, equal to the illumination of a well-lighted drafting room.

A total of six pumping units are installed. Four units, each having a rated capacity of 28 m.g.d. against a head of 365 feet, and driven by 2250 h.p. synchronous motors are arranged for pumping to Highland Reservoir No. 1. Two units of 24 m.g.d. capacity each against a head of 272 feet and driven by 1500 h.p. synchronous motors pump to Highland Reservoir No. 2. Each pumping unit consists of two 30-inch by 24 inch pumps in series, and all parts of both the large and small units, except the impellers, are interchangeable, a feature which greatly reduces the necessary stock of replacement parts. To provide additional flexibility of operation, one of the larger units is furnished with a set of spare impellers of special design for pumpage to the low head service at high efficiency.

Each pump has a 24-inch automatic cone valve, hydraulically operated, and controlled by differential pressure. This type of check valve has proved invaluable for this service, as it has entirely eliminated the danger of excessive surges in the rising mains when the pumps are stopped. As some of our rising mains have been in service for more than fifty years, we have naturally been much concerned over their ability to withstand such extra pressure. Each pump has, in addition to the cone valve, a 30-inch gate valve, and all pumps discharge into a 36-inch "trunk" in front of the station. This "trunk" has a gate valve installed between each two pump discharges for sectionalizing purposes. The three rising mains leave the trunk through 48-inch gate valves. All gate valves are motor operated, and are controlled from a special desk inside the station. On the face of this desk is a complete picture of the piping layout, with control switches and indicating lamps for each valve, so that the operation is extremely simple. All gate valves and the so called "trunk" are located in a basement in front of the station, and water-tight walls assure of sectionalizing of trouble in case of breaks. All connections are made at right angles as a matter of simplicity and to avoid the inherent weakness of Y-fittings. It might be of interest to you to know that the elimination of the old yard piping, in which every effort had been made to obtain a smooth passage of water, resulted in a decrease of friction loss of approximately 16 feet, so that the friction loss through piping and rising mains, when pumping from the new station, is only 8 to 10 feet. The length of each rising main is about 3600 feet.

All pumping units, or rather their motors, as well as motor-generator sets for excitation and crane service, are completely controlled from a control desk, centrally located on a balcony overlooking the entire pump room. All starting functions as well as protective features are entirely automatic.

The electric service is furnished by the Duquesne Light Company, which maintains a 22,000-volt outdoor transformer substation adjacent to the switchboard room. This substation is fed through two 22,000-volt underground cables from independent sources. The service enters the switchboard at 2300 volts, at which voltage all motors are operated. Switching and electrical auxiliary equipment are housed in separate rooms, and by means of steel enclosures and interlocks it has been made impossible for the men to come in contact with any energized part of the equipment carrying a dangerous voltage.

The entire station is operated by a chief engineer with three shifts of a first assistant engineer, one pumpman, and one laborer.

Electric power is purchased from the Duquesne Light Company under their standard rate for commercial and industrial users, including a clause for "off-peak" service; under this rate, which recognizes high load-factor as well as high power-factor, we are purchasing power at a net rate of approximately 6.9 mills per kilowatt-hour.

The pumping units were tested in exhaustive tests after their installation in the new station, and it was found that the efficiencies exceeded those guaranteed by the manufacturer by 1.6 to 2.1 percent; the tested efficiencies of units, pump and motor, varied from 86.2 for the small units to 87.6 percent for the large unit. Due to the efficient and economical layout of the plant we are maintaining a plant-efficiency of better than 86 percent.

The actual cost of construction of the new electric station was only $775,000.00, a saving of 14 percent of the estimated cost. This saving was mainly due to the prevailing low prices during the years 1930–1931.

In reviewing the earlier preliminary estimates of operating costs in the light of actual experiences, it appears that the engineers, who were more familiar with steam plant than with electric plant operation, were too conservative in their estimates of the electrical operation. As I have previously mentioned, the unit efficiencies obtained are far better than we expected four or five years ago. As I have also mentioned, the efficient station design resulted in lowering the operating head by about 2 percent. And not least is the savings in cost of power which is the result of a carefully supervised schedule of pumping at a high load-factor, made possible by utilizing a safe part of the approximately 243 million gallon capacity of the reservoirs to which this station is pumping.

The surprising result is, that the actual cost of operating the new electric plant is slightly below the estimated cost of operating a modern high-pressure steam plant. This assumes an average price of coal of $2.62 per ton, based on actual costs in this district for a period of years.

As a matter of interest, the annual operating cost of the new electric station is approximately $221,000.00 as against $287,000.00 for the abandoned steam plant, or a yearly saving of $66,000.00. As the fixed charges for the electric plant are only $45,400.00 yearly, they are more than paid for by this saving.

(Presented before the Central States Section meeting, October 22, 1933.)

EXPERIENCES WITH TREATING DWINDLING WATER SUPPLIES IN NORTHWESTERN MINNESOTA

By E. L. Lium

(City Engineer, Grand Forks, N. D.)

During the last few months most of you have undoubtedly been reading about the returning of North Dakota to the desert state in which it is supposed to have been at some time in the past. You have read of the efforts on the part of public works committees, governors, public officials of different capacities, and committees of all sorts in their attempts to secure public works money for the Missouri River Diversion project. You have heard of the rapidly lowering lake and ground water levels, the burning up of crops, and undoubtedly some of you have wondered what effect these conditions have had on some of your fellow-men in the waterworks industry. Unfortunately the state boundary lines do not entirely separate the conditions of one state from those of another, but there is an overlapping, and such is of course the case along the Red River of the North. In other words, portions of western Minnesota are facing the same problem as the eastern cities in North Dakota on the Red River. The rapidly dwindling river flows of the past few years have brought about some unusual conditions in a great many waterworks plants because of the tremendous concentration of pollution that has developed in very short periods of time. During the past winter, things happened that heretofore had been regarded as very improbable if not impossible.

The cities of Wahpeton and Breckenridge deriving their water supply from the Ottertail river found their intakes high and dry one morning in December with a temperature close to 20 degrees below zero, and not much to do about it except to hope that in some way or other water might come down the river. This condition had been talked of in years prior to this, but from year to year nothing happened and it began to look as if nothing ever would happen. Last year was the first time in the history of their waterworks systems, that this condition came about. I shall not attempt to go into detail covering the unusual happenings that took place when several thousand

people found to their amazement that their water supply had suddenly disappeared. The one thing that struck me in viewing the situation was the relatively small importance that our thirst requirements play in the waterworks field today. It was possible for anyone to secure drinking water or other soft drinks without much difficulty, but where the real hardships came about was in the sanitary conditions at the home, the hospitals, the hotels, the jails, and other public buildings. Fire-protection was apparently the next in importance and after that, the problem of what to do with various steam plants and hot water heating plants that had been dependent entirely upon the city supply for their water. After about a week of absolutely no flow, water was finally obtained from the Dayton Hollow dam supply near Fergus Falls. The city of Wahpeton, North Dakota was fortunate in having an old well that could be thrown into operation hurriedly and by means of an air compressor and piping, water was obtained in a short time and the city was carried over the period of no flow in the river without any actual shortage of water.

The two cities of East Grand Forks, Minnesota and Grand Forks, North Dakota derive their water supply from the Red Lake River which joins the Red River of the North at this point. The Red Lake river, as most of you know, has its source in Red Lake, a large body of water in northern Minnesota on the Red Lake Indian Reservation. It is also fed by the Clear Water river which joins it at Red Lake Falls, and it has its source in Clear Water Lake which is south of Red Lake. Unfortunately Red Lake has been lowering rapidly during the last few years and where people used to go in steam boats it has now become possible to travel by car. Our two cities were fortunate in receiving some flow from the Clear Water river during the past two years, and without this flow we would have had to resort to the Red River of the North. A great many attempts at water conservation have been made including the building of dams at the lakes, but all such attempts help little when there is no excess water to conserve.

TREATMENT DIFFICULTIES

Coming now to the treatment problem itself, it will be necessary to describe local conditions in our two cities. Eight years ago a dam was constructed across the Red River of the North, below all the sewers, in order that a higher water level might be maintained through the cities of Grand Forks, North Dakota and East Grand Forks, Minnesota. This dam supposedly was to serve two purposes.

First, to submerge all local sewer outlets and supply sufficient dilution to the sewage so that all odors that had become quite obnoxious would be done away with. Second, to stabilize sliding banks, and beautify the river and provide recreational facilities such as boating and swimming. Shortly after the construction of this dam, the American Beet Sugar Company located a plant in the city of East Grand Forks, Minnesota. They located their water intake above the intakes of the two cities in the Red Lake river and placed their sewer outlet above the dam across the Red River which is below the junction of the Red River and Red Lake River. During the last year when the Red River froze solid to the bottom about 30 miles south of Grand Forks, and the Red Lake River practically ceased to flow, we had virtually a lake of water created by the impounding of the local dam. From this lake the Beet Sugar Company's plant was drawing water from one end and depositing an equal amount of sewage or waste matter in the other end. Resulting from this condition was a slow circulating motion in the lake which was at times very much increased by the action of the wind prior to the freezing of the ice. The resulting problem of water treatment became extremely difficult because everything went beyond what one might regard as reasonable limits.

During August, 1932, the raw water bacteria counts averaged 1804 per cubic centimeter and in a great many cases, we found no indication of B. Coli in our 1-cc. samples.

During September the American Beet Sugar Company's plant began operating and the average bacteria count became 4040 per cubic centimeter with only two or three findings of no B. Coli in our daily 1-cc. samples.

The concentration in the lake or pond became considerably heavier during October and the average bacteria count per cubic centimeter amounted to 89,728 with a peak of 1,100,000 and we failed to find any single 1-cc. sample without evidence of B. Coli. During this month, we had a local rain amounting to about 1 inch of precipitation in a time of about 5 hours. This created an unusual flow in our combined sewerage system which also empties into the so-called lake and the resulting jump in bacterial count was tremendous, going from 7,000 to 1,100,000 per cubic centimeter in a period of five days. The Grand Forks plant is of the excess lime and soda ash softening plant type and little difficulty was encountered in removing the bacteria, but we did not fare so well from the standpoint of odor and taste removal. The raw water became a decidedly black color with an

intense sewage odor, and it was loaded with all types of domestic wastes as well as gas plant waste products. The resulting tastes were of a chlorophenol type and became so pronounced that for about two days the taste was transmitted to cooked food, coffee and tea, and a great number of complaints were registered with the water department. By increasing the dosage to 200 pounds of powdered charcoal per million gallons of water, in addition to the use of an upward flow charcoal bed and stepping the ammonia dosage up to an equal amount with the chlorine dosage, it was possible to bring the water back to a fairly palatable product in a very short time.

Some water came down the river during November and nothing of any unusual interest took place. The bacteria count per cubic centimeter averaged only 705.

Conditions began to get worse and continued to become worse through the entire month of December. The bacteria count ranged from as low as 90 per cubic centimeter in the first few days of the month to a peak of 150,000 per cubic centimeter during the last few days of the month, with an average of 27,120 per cubic centimeter for the month. B. Coli was present in all 1-cc. samples taken. After the ice had formed on the river it was quite evident that the water was fast increasing in B.O.D. demand and the formation of hydrogen sulphide began to take place as the by-product of the decomposition of beet sugar and domestic sewage wastes together with the decomposition of vegetable matter in the bed of the river that might be attributed to algae and other plant growths. The chlorine dosage which normally amounted to from 11 to 13 pounds per day was increased to 60 pounds per day by the last of December. Even with such tremendous increase, it was impossible to retain residual chlorine in the tap water. The cost of chemicals per day in the treatment process during this month climbed from $34.00 to $77.00 per million gallons.

This can be attributed to the increase of activated carbon as well as that of chlorine. Conditions were steadily getting worse and shortly after Christmas the raw water began to change its color. It gradually became a bluish color and finally reached the color of blue india ink. This was undoubtedly due to the suspended colloidal matter in the water and one of its peculiarities was that upon being placed in a glass jar in the open day light it soon lost its bluish color and became more of a milky shade.

The hydrogen sulphide content increased steadily from day to

day during January and the chlorine demand kept increasing steadily. It was necessary to change our vacuum type chlorine machine in order that its capacity might be increased to a 100 pounds per day, and besides that it was necessary to use two other chlorinators before any residual could be found at any point in the plant. We finally resorted to chlorination at three places: (1) On the incoming raw water. (2) Directly before sand filtration. (3) After sand filtration, but prior to charcoal filtration. Chlorine dosage increased from 60 to 160 pounds per million gallons. Ammonia dosage increased from 14 to 50 pounds per million gallons. Ammoniation was applied directly before first chlorination on the raw water. In terms of grains per gallon this represented a maximum chlorine dosage of about $\frac{9}{10}$ grain per gallon or about 15 parts per million. The charcoal dosage steadily increased during the month of January from 210 to a maximum of 715 pounds per million gallons. During the month of January the bacterial count naturally became considerably less than it had earlier during the winter because of the low temperature of the water and the resulting slower growth of bacteria. The average bacteria count per month was 10,700 per cubic centimeter running from a maximum of 55,000 to a minimum of 2500, but in all 1-cc. samples taken, B. Coli were indicated. In spite of the chlorine dosage used, which amounted to an average for the month of about 0.65 grain per gallon, we failed to carry a residual chlorine in the tap water with the exception of eight days during the first half of the month. We were able to maintain a water that was entirely satisfactory from a bacterial standpoint with the highest bacteria count in the tap water being 3 per cubic centimeter and at no times any evidence of the B. Coli in 50 cc. samples.

During this period of increasing pollution we maintained a tap water of fair quality from the standpoint of taste, but it was not difficult to detect tastes developed during the manufacturing process. Restaurants and hotels used the water during the entire time and the majority of the people in the residential section continued using the tap water. There was of course an abnormal increase in the use of bottled waters and the money expended for this purpose must have amounted to a good many thousand dollars for the city as a whole.

Conditions continued to become more severe and it began to look like a hopeless fight. Mr. McKinnon, Chief Engineer of Public Works at Winnipeg, kept us in touch with conditions at the Manitoba Agricultural College where they are using the water from the

Red River. He advised us from time to time of the different methods he used and they included the aeration of the treated water in the elevated standpipe, chlorination at three points, ozone, potassium permanganate, super chlorination, and activated carbon. The raw water became so severely loaded, however, that all methods failed and they were forced to use other water for drinking purposes. On the strength of Mr. McKinnon's recommendation regarding the results obtained from aerating in his elevated tank, we inserted aeration into our clear well, but noticed no appreciable advantage therefrom. About this time (the latter part of January) we were wondering how we might pull through the winter.

Periodically we would travel up the Red Lake River, cut holes in the ice, and ascertain whether there was any water still coming down. In our trips we used to take samples from the top of the river, and we found that these samples would not coincide with the samples taken from our intake pipes at the plant. We then began taking samples from the top of the pond or lake and the bottom at the same time, and we were surprised to find that while the bacteria count at the top would be as low as 300 per cubic centimeter, at the bottom it was as high as 10,000 per cubic centimeter. The water at the bottom was blue as ink and at the top was fairly clear. The difference in total hardness from top to bottom amounted to about 100 parts per million.

On the strength of these findings we placed the suction pipe of the East Grand Forks plant near the surface of the pond and immediately on doing that we found a much better water and were able to turn out a tap water at about one-half the cost that we had reached with the water from the bottom of the river. In the Grand Forks plant by the first of February we had reached a treatment cost running close to $140.00 per million gallons in chemicals alone. In order to take advantage of the top water for the Grand Forks plant we constructed a barge out of large timbers and placed thereon a horizontal centrifugal pump and pumped the surface water into the intake crib at such an elevation that we were able to derive considerable aeration in the intake crib. This pump was thrown into operation on February 7, and as soon as it was started the chlorine dosage dropped from 150 to 25 pounds per million gallons. The charcoal dosage dropped from 700 to 350 pounds per million gallons. The ammonia dosage dropped from 35 to 25 pounds per million gallons. We immediately produced a much tastier and better product and were able to pull

through February with a cost of treatment the same as that for the month of January.

During March, the spring thaws brought sufficient dilution down the river to return conditions almost to a normal stage.

During the peak of bad water conditions in the winter time the hydrogen-sulphide content of the raw water was so great that the plant operators could not stay in the building with the raw water because of the intensity of the odors. All metal fittings in the building plated out black and it was possible to turn a lead solution black by holding a cloth saturated with it over the mouth of a jug filled with raw water. The plants in both cities were surrounded with bad odors and you could smell the raw water when you were within twenty feet of the door of the plant.

This condition was of course caused entirely by low water conditions and lack of sewage disposal facilities. We are facing a winter condition for the coming months as serious as that of last year, but we feel that with the knowledge gained from fighting the proposition during the past winter, we will be better equipped for the coming battle and hope to get through to the spring runoff without any great difficulty.

(Presented before the Minnesota Section meeting, October, 1933.)

INVESTIGATION OF GROUND-WATER IN THE ELIZABETH CITY AREA, NORTH CAROLINA[1]

By S. W. Lohman

(Junior Geologist, U. S. Geological Survey, Washington, D. C.)

Elizabeth City is in the northeast corner of North Carolina. (See fig. 1.) It lies along the northeast border of Pasquotank County, on the west bank of the Pasquotank River, which empties into Albemarle Sound. The area covered by this paper includes the parts of Camden and Pasquotank Counties lying within a radius of 10 miles of Elizabeth City. (See fig. 2.)

Fig. 1. Index Map of North Carolina

PURPOSE OF THE INVESTIGATION

The present source of water supply for Elizabeth City is Knobbs Creek, a branch of the Pasquotank River which enters the river on the northwest edge of the city. In each of the three years 1930, 1931, and 1932, there was a notable deficiency of rainfall, and consequently of stream flow, in the vicinity of Elizabeth City. At certain times each year the chloride content of the water (which is an indication of its saltiness) became noticeably high. According to R. W. Luther, superintendent of the filtration plant, the maximum chloride content, which was reached in 1930, was about 5,000 parts per million. In contrast, during the spring of 1932, when there was abundant

[1] Published by permission of the Director of the United States Geological Survey and the Director of the North Carolina Department of Conservation and Development.

stream flow, the chloride content dropped as low as 15 to 20 parts per million, but the following November it rose again to 1,800 parts.

The purpose of this investigation was to determine the possibility of developing a ground-water supply that would be adequate for the needs of the city, either permanently, or as an auxiliary supply during certain periods when the present Knobbs Creek supply might again become salty.

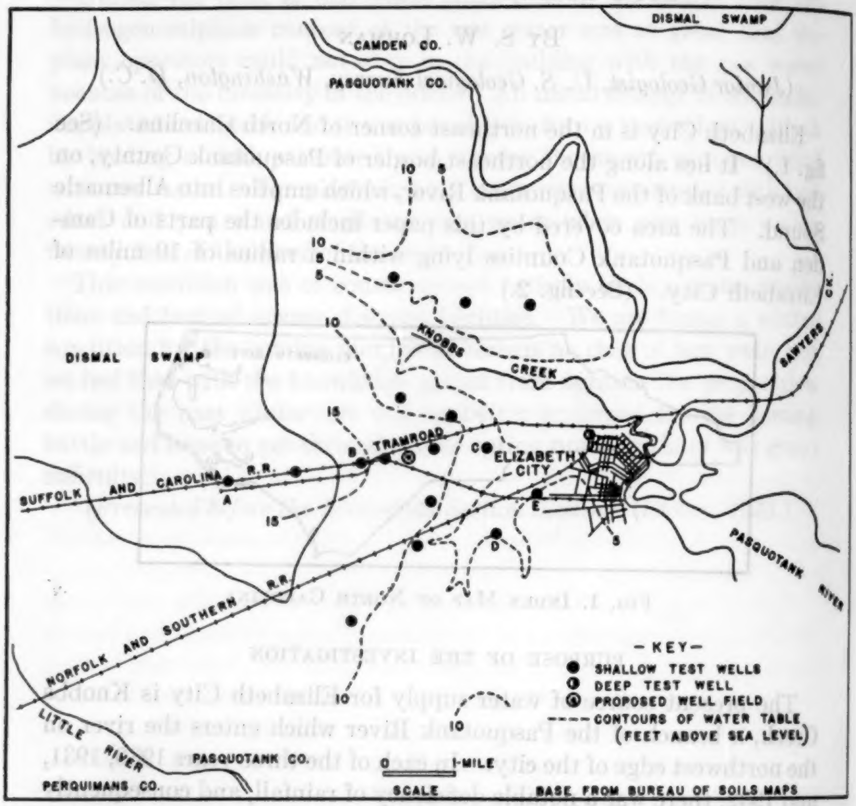


FIG. 2. MAP OF ELIZABETH CITY AND VICINITY SHOWING THE LOCATION OF TEST WELLS AND WATER TABLE CONTOURS

A preliminary investigation was made in September, 1932, by David G. Thompson, of the United States Geological Survey. In a brief report Mr. Thompson pointed out that the available information did not indicate an easy solution to the problem of obtaining an adequate and permanent supply of good water, for the physical condi-

tions are such that it would be difficult to protect Knobbs Creek from contamination by salt water, and the quantity of water available from the creek during a prolonged drought might not be sufficient for the public supply. The meager information in regard to deep wells indicated that all water below a depth of 300 feet, and possibly at lesser depths, is too salty for use. Analyses of water from several wells indicated that the best water could probably be obtained from shallow wells situated far enough from the salty streams so that they would not become contaminated during heavy pumping. However, the information did not indicate where such areas were to be found nor whether the supply would be adequate. It was therefore recommended that before any development of shallow wells was planned, tests should be made to determine whether and where good water-bearing materials are to be found and whether the supply would be sufficient to meet the needs of the city.

Subsequently an agreement was entered into between the United States Geological Survey and the North Carolina Department of Conservation and Development whereby an investigation was financed on a 50–50 basis in accordance with a provision in the Federal law appropriating funds for investigations of water resources by the Geological Survey. The State was, in turn, reimbursed by Elizabeth City for part of its contribution, and also under the terms of the agreement the city paid all the expenses for extensive test drilling and test pumping. This work was under the direction of J. C. Parker superintendent of the Elizabeth City Public Utilities Commission. The writer was assigned to the investigation in November, 1932.

PHYSICAL AND GEOLOGIC CONDITIONS

The surface of Pasquotank and Camden Counties is low and nearly level and lies entirely within the lowest or Pamlico terrace of the Pleistocene, in the Coastal Plain province. A large part of Elizabeth City and vicinity lies between 5 and 10 feet above sea level, and the highest part of the area covered has an altitude of only 17 feet. Parts of the Dismal Swamp lie within the area, and Knobbs Creek drains several small swamps, some of which lie within the city limits of Elizabeth City. The area is drained entirely by the Pasquotank River and its tributaries. Natural drainage on the farm lands in interstream areas is poor, necessitating numerous drainage ditches.

The climate of Elizabeth City is characterized by long summers and comparatively short, mild winters. The mean annual precipitation is about 48 inches.

The surface of Pasquotank and Camden Counties is underlain by fine sands and sandy loams of the Pamlico formation to a depth of not more than 30 feet. These deposits conceal beds of Pleistocene or Pliocene age or both, and at greater depth there are beds of Miocene age. At an undetermined depth, but probably about 700 or 800 feet below the surface, the Tertiary deposits are underlain by strata of Cretaceous age. The beds all lie nearly horizontal but dip toward the coast at a very low angle. The test wells put down in and near Elizabeth City yielded many fossils that were of great value in determining the age of the concealed strata.

OUTLINE OF PRINCIPAL WATER-BEARING BEDS

The fine-grained sands of the Pamlico formation supply most of the water for domestic use, and the water is recovered by means of shallow dug or driven wells. In addition to the shallow beds there are several deeper artesian strata. A few jetted wells in the city obtain potable water from depths of 70 to 100 feet, but water encountered below a depth of 300 feet is likely to be too salty for ordinary use.

DEEP TEST WELL

Prior to the signing of the coöperative agreement, on the recommendation of H. J. Bryson, State geologist, the city undertook the drilling of a 6-inch test well at the filtration plant in order to test thoroughly the deeper water-bearing formations. (See fig. 2.) Samples of material were collected every 5 feet and were later examined for fossils by paleontologists of the Geological Survey, and the physical properties of the water-bearing sands were investigated in the hydrologic laboratory of the Survey by V. C. Fishel.

Only fine sand and silt were encountered down to a depth of 75 feet, where 18 feet of good medium to coarse grained water-bearing sand was penetrated. A thorough test at this depth was postponed until the completion of the drilling. Between the depths of 93 and 480 feet the strata consisted principally of clay, which in some places was mixed with fine sand and silt. After passing through 2 feet of very hard sandstone, a water-bearing sand of unknown thickness was encountered at a depth of 482 feet, from which the water rose one foot above the ground level.

A pumping test at this depth with a small sewer pump gave a yield of 62 gallons a minute, with a draw-down of 6.7 feet. This test was made under very poor conditions, for part of the hole was not cased, no well screen was used, and the well penetrated only the top of the

water-bearing sand. To judge from the specific capacity of the well, 9.25 gallon a minute per foot of draw-down, much more water undoubtedly could be obtained at this depth if the well were properly finished and a larger pump were used. Unfortunately an analysis of the water showed a chloride content of 3,280 parts per million, and drilling was therefore stopped at 482 feet.

The well casing was then withdrawn, a cement plug was set near the bottom of the well, and the hole was filled with clay up to the sand at 93 feet to prevent the salty water below from contaminating the upper strata. The sand from 75 to 93 feet was also tested without a well screen. The well was pumped at rates of 150 to 198 gallons a minute, and the maximum draw-down at 198 gallons a minute was 19½ feet, giving a specific capacity of 10 gallons a minute per foot of draw-down.

An analysis of water from this sand when first drilled showed only 190 parts per million of chloride, whereas a number of samples collected during the preliminary pumping test contained from 277 to 314 parts per million. It was concluded that this rise in chloride content was produced by saline water from the 482-foot sand, which, having a greater artesian pressure, had escaped into the upper sand during a period of several days when the drillers were trying to recover a lost string of casing. Accordingly, the well was bailed down to a depth of about 125 feet, and a wooden plug was driven into the top of the lost string of casing followed by a cement and clay seal.

The pump was again started and the well was pumped almost continuously for a week at a rate of about 158 gallons a minute, with a 15-foot draw-down. Samples of water were analyzed at intervals, and a sample taken at the end of the week contained the following:

Constituents	*Parts per million*
Silica (SiO_2)	53
Iron (Fe)	0.23
Calcium (Ca)	66
Magnesium (Mg)	46
Sodium (Na)	197
Potassium (K)	22
Carbonate (CO_3)	0
Bicarbonate (HCO_3)	469
Sulphate (SO_4)	3.3
Chloride (Cl)	308
Nitrate (NO_3)	0.10
Hardness (calculated)	358
Total dissolved solids	925

It is believed that with prolonged pumping the salt water might perhaps have been removed, but even with a reduced chloride content the hardness of the water would render it objectionable for municipal use. This deep test well was therefore abandoned, but it was recognized that if an adequate supply of shallow ground water was not found, there remained the alternative of developing an auxiliary supply from the 75 to 93 foot sand.

SHALLOW TEST WELLS

In determining whether it would be feasible to develop a water supply from shallow wells it was necessary to give attention especially to two factors, first, whether the water-bearing materials are capable of yielding the required quantity of water; second, whether salt-water contamination would result with continued pumping. At several places in Elizabeth City fairly large quantities of water have been obtained from wells of small diameter drawing from the shallow beds, and this fact led to the belief that the desired quantity of water might be obtained from similar shallow wells. The chloride content of the water from these wells generally increased when they were pumped heavily, and it was feared that wells used for public supply in the city would soon become salty. However, a consideration of the principles governing the relations between fresh and salt water indicates that the danger of contamination would be less in some localities than in others.

The danger of contamination depends upon the relations which exist between the fresh and salt waters near seacoasts, and certain precautions must be observed. The fundamental facts to be understood in regard to these relations are as follows: (1) Where bodies of fresh and salt water are in contact the salt water, being heavier than the fresh, will lie below the fresh water—in other words, the fresh water floats, so to speak, on the salt water. (2) The depth to the contact between the fresh and salt water is a function of the altitude of the water table above sea level and of the density of the salt water. This may be expressed by the simple formula

$$h = \frac{t}{g - 1},$$

in which h is the depth of the fresh water below sea level, t is the height of the fresh water above sea level, or hydrostatic head, and g is the density of the salt water. The density of ocean water is about

1.025. From these relations, if the fresh-water head is 2.5 feet above sea level the fresh water will extend 100 feet below sea level. In other words, for each foot of fresh water above sea level the fresh water extends about 40 feet below sea level. If the water-bearing material is more or less homogeneous and permeable in all directions toward bodies of salty water, such as the Pasquotank River and Little River, and downward to the beds containing salt water that are known to lie beneath Elizabeth City at a greater or less depth, then if the water table is lowered to sea level or below there is danger of contamination by either horizontal or vertical (upward) movement. If, however, the water table near the pumped wells can be maintained a foot or two above sea level, according to the principles enunciated it should be possible to pump water from wells 25 feet deep without danger of contamination. Furthermore, if the shallow water-bearing beds are underlain by an impervious bed that would prohibit upward movement of salt water from underlying beds, it would probably be possible to draw down the water level in pumped wells a few feet below sea level if between the wells and any surface sources of salt water the water table were maintained at an altitude high enough above sea level to provide a barrier of fresh water around the wells. The possible situations are illustrated in figure 3.

In accordance with the principles governing the relation between salt and fresh water, it is evident that the fairly high chloride content in the shallow wells in Elizabeth City is to be explained by their closeness to the salty Pasquotank River. The water table is not much above the river, and a comparatively small lowering of the water table by pumping has permitted the salt water to move into the water-bearing formations.

Because of these relations an essential consideration, if shallow wells are not to be contaminated, is to locate them where the water table is highest above sea level, provided, of course, that the water-bearing material is everywhere equally permeable. To determine the most favorable localities it is necessary to construct a contour map of the water table.

For this purpose the character of the water table in a number of privately owned shallow wells was determined. From measurements of the depth to water level in these wells on January 18 and 19, the water-table contour map shown in figure 2 was constructed. This map shows that in the area between Knobbs Creek and the Pasquotank River the water table stands not higher than 5 feet above sea

level in most places and reaches a height of 10 feet above sea level in only a few places. Similar conditions are found over much of the area northwest and south of Elizabeth City, but in the area about 3 miles west of the city the water table is more than 15 feet above sea level.

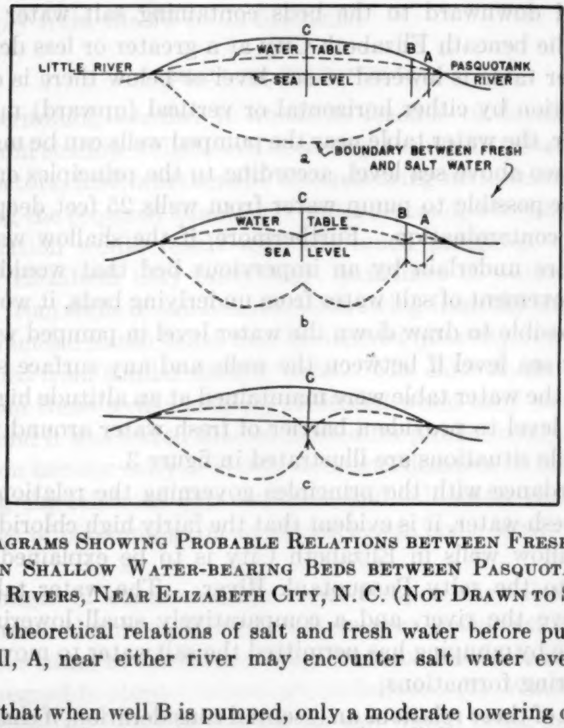


Fig. 3. Diagrams Showing Probable Relations between Fresh and Salt Water in Shallow Water-bearing Beds between Pasquotank and Little Rivers, Near Elizabeth City, N. C. (Not Drawn to Scale)

a shows theoretical relations of salt and fresh water before pumping. A shallow well, A, near either river may encounter salt water even without pumping.

b shows that when well B is pumped, only a moderate lowering of the head may result in drawing in salt water, whereas in well C an equal lowering of head may not result in drawing in salt water.

c shows that too great a lowering of the head in well C may also result in drawing in salt water.

While the leveling work was under way, a local well man was employed by the city to put down several shallow 1¼-inch test wells, under the writer's direction, the locations of which are shown in figure 2. The wells were jetted down with a small pump, and samples of the water and of the sand or clay were obtained at different depths for analysis in the laboratories of the Geological Survey.

The test wells put down in the area between Knobbs Creek and the

Pasquotank River revealed fine sand down to depths of 20 to 42 feet, under which a bed of clay was encountered. The sand beds were discontinuous, and much of the sand contained considerable silt and shells. Because of the discontinuous nature of the sand beds, the proximity to the Pasquotank River and Knobbs Creek, and the low altitude of the water table, this area was unsuited to the development of a shallow ground-water supply.

The results obtained from most of the shallow test wells west of the city are shown in figure 4. The thickest beds of sand and highest water levels were encountered in the two westernmost test wells, put down in the Dismal Swamp. However, analyses of the water at different depths in these wells showed that the ground water is very hard, owing to numerous beds of marine shells, and contains a large amount of iron, although the chloride content in all the shallow test wells is very low.

The most favorable area borders the Dismal Swamp on the east, where a large part of the surface is underlain by 25 to 30 feet of fine sand resting on a thick bed of clay. Although the sand here is not as thick as it is within the swamp, it is uniform and continuous over several square miles, the water table stands nearly as high as in the swamp, and the water is softer and contains less iron.

Mechanical analyses of sand samples by V. C. Fishel in the hydrologic laboratory of the Geological Survey showed that 65 to 75 percent of the particles are fine sand, with a grain size of 0.125 to 0.25 millimeter, and a small percentage are classed as medium sand or very fine sand. The coefficient of permeability was determined on several samples, and the figures compared favorably with those of samples collected from the 75 to 93 foot stratum, with coefficients ranging from 475 to 725. (For definition of coefficient of permeability see figure 5.) These samples of sand were collected while the test wells were being jetted; consequently some of the finer materials were washed away, but it was generally possible to estimate how much fine silt came up. The shallow test wells were equipped with 5-foot 1¼-inch 60-mesh well screens and were pumped with a pitcher pump at different depths for the water samples. It was noted that most of the wells cleared up rapidly and yielded water freely.

The depth to the water level in several shallow wells in the area was measured from time to time by Messrs. J. C. Parker, R. W. Luther, and the writer. The wells west of the city fluctuated from 2 to 7 feet. The water level in wells that were measured before and after a rain

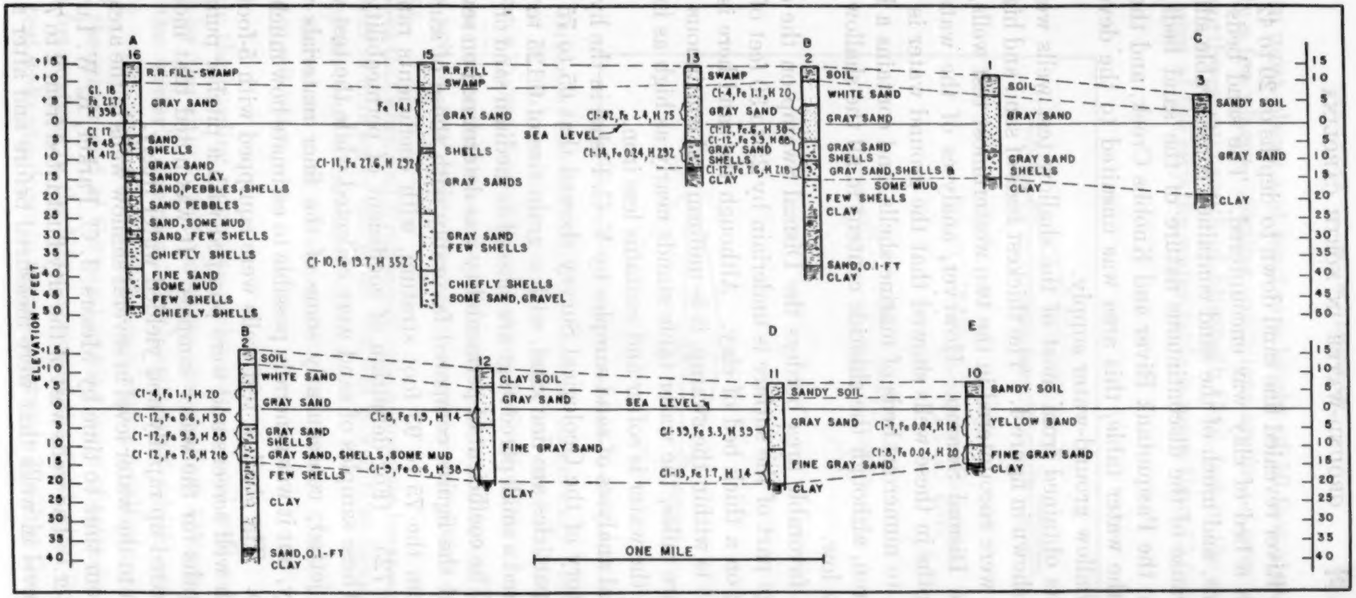


FIG. 4. CROSS SECTIONS OF TEST WELLS ALONG LINES AC AND BE WEST OF ELIZABETH CITY, N. C. SHOWING ELEVATIONS, WELL LOGS, AND ANALYSES OF WATER

of several days commonly rose from 1 to 2 feet, indicating that the rainfall was not appreciably hindered from reaching the water table and that recharge was fairly rapid.

For a population of 10,037 in 1930, the city's minimum daily water requirement was about 600,000 gallons, or about 416 gallons a minute. Estimates based on the porosity and thickness of saturated sand west of Elizabeth City indicated that each square mile of saturated sand contains sufficient water in storage to supply the city for more than three years without additional recharge from rainfall. It was realized, however, that because of the fineness of the sand and the relatively low permeability it would be difficult to get the water out of the sand at the required rate.

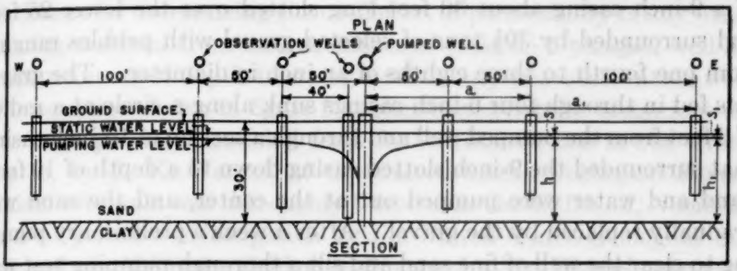


FIG. 5. PLAN AND SECTION SHOWING THE ARRANGEMENT OF WELLS AND GROUND WATER CONDITIONS DURING A PUMPING TEST ON A SHALLOW GRAVEL-WALL WELL NEAR ELIZABETH CITY, NORTH CAROLINA

The permeability of the water bearing sand was obtained by applying Thiem's formula modified by L. K. Wenzel.

$$P = \frac{527.7\, q \log \frac{a_1}{a}}{\frac{h + h_1}{2}\,(s - s_1)}$$

P = Coefficient of permeability, which may be expressed as the number of gallons of water a day at 60°F., that is conducted laterally through each mile of the water-bearing bed under investigation (measured at right angles to the direction of flow), for each foot of thickness of the bed and for each foot per mile of hydraulic gradient.

q = Yield of pumped well in gallons a minute.

a, a_1 = Distances of any two observation wells from the pumped well.

s, s_1 = Drawdowns at any two observation wells.

h, h_1 = Thicknesses of saturated water-bearing material at any two observation wells.

With all the factors in mind, it was deemed desirable to drill a large well to test the water-yielding capacity of the shallow beds, and a locality was suggested.

GRAVEL-WALL TEST WELL

The city took an option on some property at the location shown in figure 2, and a gravel-wall well was put down. This well consists of a 9-inch casing about 30 feet long slotted over the lower 25 feet and surrounded by 39½ tons of selected gravel with pebbles ranging from one fourth to three eighths of an inch in diameter. The gravel was fed in through four 6-inch casings sunk along a circle at a radius of 3 feet from the pumped well and through a section of 10-inch casing that surrounded the 9-inch slotted casing down to a depth of 10 feet. Sand and water were pumped out at the center, and the sand was gradually replaced by the gravel. After a week's preliminary pumping to clear the well of fine sand and silt a thorough pumping test was made.

As shown in figure 5, six 1¼-inch driven wells equipped with ordinary screened well points were put down along a straight east-west line at distances of 50, 100, and 200 feet from the pumped well, and one well was put down 10 feet from the pumped well. In addition, a well was dug 1,000 feet east of the pumped well and equipped with a 7-day automatic water-stage recorder, in order to observe whether the effect of pumping could be detected for a distance of 1,000 feet. The exact altitude of the top of each well was then determined with reference to the pumped well.

After the static water level in each well had been accurately measured, the pump was started and the depth to water was then measured hourly at each well. It was intended to pump the well day and night for a week or more, but trouble with the pump necessitated brief stops at intervals.

Figure 5 shows the slope of the water table (known as the cone of depression) after 31 hours of continuous pumping at an average rate of 40½ gallons a minute. With a static water level of 3½ feet below ground level, the draw-down in the pumped well was 19½ feet, giving a specific capacity of only a little more than 2 gallons a minute per foot of draw-down. Only about 10 feet of the strainer was completely submerged, but doubtless some water seeped in higher up. This yield was considerably below the expected yield, and the reason appears to be that the fine sand contained considerable silt and was

therefore less permeable than the samples collected for analysis in the laboratory. Moreover, it was found that the material around the gravel-wall well contained more silt than that in most of the adjacent territory.

The formula shown in figure 5 was then applied to the data collected in order to determine the permeability of the sand as it occurs in nature. This formula was originally developed in Germany by G. Thiem for determining the coefficient of permeability of any water-bearing material from measurements of yield on a pumped well and measurements of depth to water level on any two observation wells. The equation shown in figure 5 applies to water-table conditions and has been put in a modified form for convenient use in the United States, by L. K. Wenzel, of the United States Geological Survey. Thiem's formula was thoroughly tested near Grand Island, Nebraska, in a coöperative investigation by the United States Geological Survey and the Nebraska Geological Survey, by Mr. Wenzel, who ran a number of 48-hour pumping tests, using 81 observation wells spaced 2 to 1,200 feet from the pumped well. The formula held true after the slope of the water table between the observation wells became constant, even though the water level might still be slowly declining.

By applying Thiem's formula (using all combinations of wells) it was found that the coefficient of permeability was only about 250, whereas the partly washed samples tested in the laboratory had coefficients ranging from 475 to 775, and those from the immediate vicinity of the test well from 500 to 600. With this lower permeability the sand will allow a correspondingly smaller amount of water to flow through it.

The well was pumped almost continuously for nearly a month at about the same rate. The maximum drop in water level in the observation well 200 feet from the pumped well was less than 1 foot. It is not certain whether the pumping affected the water table in the observation well 1,000 feet away, because numerous rains occurred during the test period and caused appreciable recharge, but at least there was no significant effect.

Samples of water were collected at intervals throughout the month. The following is a partial analysis by E. W. Lohr, of the Geological Survey, of a sample of water collected July 31, 1933, after the pump had been running a month.

Analysis by E. W. Lohr, U. S. Geological Survey.

Constituents	*Parts per million*
Iron (Fe)	8.4
Calcium (Ca)	45
Sodium and potassium (Na K)	13
Carbonate (CO_3)	0
Bicarbonate (HCO_3)	204
Sulphate (SO_4)	5
Chloride (Cl)	15
Hardness	165

This analysis shows a negligible content of chloride, but the hardness and the iron content are considerably greater than that of samples of water collected in the same area during the exploratory test drilling. This difference may be due to the fact that continued pumping brought in some water from the west, where the hard iron-bearing water stands at a slightly higher altitude. However, the iron content and hardness can readily be reduced by treatment in the existing filtration plant. Because of its low chloride and sulphate content, this water is superior to that obtainable from the 75 to 93 foot sand.

The yearly water requirements of the city are about 675 acre-feet. On the assumption that sand throughout the area has a coefficient of permeability of only 250, as obtained by Thiem's method, and with the average natural hydraulic gradient of 3 to 4 feet a mile and a thickness of 25 feet of saturated sand, the amount of water flowing into each square mile from the adjacent territory is only 25 to 30 acre-feet a year. Obviously, in order to obtain the required quantity of water most of it must be drawn from storage or obtained from recharge from precipitation. A large quantity of water is stored in the ground, but it is not desirable to take water from storage, for if that were done the supply would soon be exhausted. On the data obtained as to the character of the sandy soil underlying the surface and the response of the water table to rainfall, it would seem to be a reasonable assumption that one fourth of the average annual rainfall of about 48 inches, or 12 inches, penetrates to the water table and becomes available as recharge. On this assumption the recharge from rainfall amounts to 640 acre-feet a year. The water available from recharge on one square mile and by percolation from the adjacent territory is thus estimated to be about equal to the yearly water requirements without drawing upon water in storage. Of course,

during dry periods the supply must come largely from storage, but there should be opportunity for replenishment during subsequent wetter periods.

In view of these conditions it was considered likely that better results might be obtained by using a large number of wells of small diameter scattered over one square mile or more and spaced sufficiently far apart to prevent much interference. This method would have the advantage of drawing water from numerous points within the area without the water moving a long distance to the pumped wells, with consequent loss of head in the sand of low permeability; the draw-down at any one point would be less, with consequent less danger of lowering the head to such an extent as to pull in salt water; and the cost would be much less than for the installation of gravel-wall wells of large diameter.

A trial group of nine jetted wells was then put down by the Public Utilities Commission a short distance from the gravel-wall test well. The wells were all equipped at the lower end with 5-foot well screens wrapped with 60-mesh screen. The nine wells were connected to a single pump, and the combined yield was 80 gallons a minute, giving an average of about 9 gallons a minute per well. A second group of 36 wells was next put down, but they have not yet been pumped.

From the results of the tests so far made with the wells of small diameter it appears that an adequate supply of water can be obtained, but it will probably be necessary to provide additional wells covering a larger area. It will be necessary to install a pipe line and power lines about 3 miles long and a central pumping plant or several smaller pumping plants. It is understood that the city plans to do this work if funds can be obtained from the Federal Emergency Public Works Administration. Plans for this project have been prepared by W. M. Piatt.

In closing, certain facts in regard to the Elizabeth City study may be emphasized. First, in contrast to many other parts of the Atlantic Coastal Plain, where it is generally possible to obtain large quantities of water from wells, in the Elizabeth City area the widespread occurrence of salt water in the shallow formations greatly reduces the opportunity of obtaining an adequate supply; and even the shallow beds are not very permeable. There is reason to believe that similar unfavorable conditions exist at other localities on the Coastal Plain in North Carolina. However, the study at Elizabeth City and an earlier study by the Geological Survey at New Bern give some hope

that in at least some of these localities adequate supplies of good water can be obtained.

Second, because of inadequate information as to the nature, location, and extent of possible suitable shallow water-bearing strata it was necessary to do a considerable amount of test work. Although this has involved some expense, it has been well worth while, for without it extensive ground-water developments might have been undertaken which, if unsuccessful, would have meant the complete loss of a much larger sum of money. The results are of substantial value to the Geological Survey in its work of determining the ground water resources of the entire Coastal Plain province.

Third, the test work was not done in a haphazard manner but was based on the application of certain well-understood principles of geology, hydrology, and physical relations between salt and fresh water.

Fourth, it is noteworthy that the most modern type of well—the gravel-wall well with turbine pump—is not suited to the conditions existing at Elizabeth City, and recourse has been had to the older method of pumping by suction from groups of wells of small diameter.

(Presented before the North Carolina Section meeting, November 13, 1933.)

THE STERILIZATION OF DRINKING WATER BY SILVER COATED SAND

By S. V. Moiseev

(The Leningrad Branch of the Union Scientific Research Institute of Water Supply and Sanitary Engineering, Leningrad, Russia)

The experimental work on the above theme had been carried out by us during the period from October, 1930, until August, 1931. For the silvering of the sand we used a method, which, as far as we know from the literature, has never so far been applied for this purpose by any previous investigator. As the result of the laboratory investigation we have prepared 145 different silver coated sands. The disinfecting power of each of them was studied on B. Coli, white staphylococcus suppurative, B. typhoid fever, paratyphoid A and B. dysentery and the cholera vibrio. Of all the sands prepared the cheapest and one possessing the greatest microbicide power and stability proved to be the silver coated sand N 56, having at the same time the physical properties favorable to its practical application as a drinking water disinfectant. The present work is the first record of our research at the experimental laboratory plant during June and July of 1931

All the authors, who had previously occupied themselves with the problem of the sterilization of drinking water by means of silver or other metals, emphasized the necessity of a preliminary liberation from the water of suspended matter and sediment contained in it, for instance, by thorough filtration. It is imperative, that the suspended matter contained in the water to be sterilized should not clog the surface of the silver and thereby mechanically produce a weakening or even total cessation of its disinfecting or olygodynamic action.

As is widely known, the olgodynamic property of metals and their salts was discovered by Nägeli in the year 1893 (1). H. Bechhold (2, 3, 4, 5) who first silvered over the coal, the bolus and finely dispersed silicic acid, pointed out the expediency of the application of the silvered coated small grained substances for the purpose of sterilization of drinking water. During the world war a flask was designed for the purpose of water sterilization, in military field conditions, by

means of silver coated grains of coal. The method of preparation of the katadyn silver and katadyn sand developed by G. A. Krause, as well as the jar for water sterilization by katadyn silver, quoted from Siebeneicher (6) are chiefly based on his researches and his patents. In his works G. Krause (7, 8) emphasizes the fact that for a reliable disinfection of drinking water by means of katadyn silver not the total amount of water is important, but rather the quantity of the suspended matter contained in it, and which is to be removed from it to ensure the normal operation of the sterilization jar devised by him with a capacity of 25 to 100 litres of water. The Sud German Serum Institute has even designed a special home filter connected with the tap. These filters first thoroughly liberate the water from suspended matter, similar to the bacteriological filters (of Berkefeld and others), and then disinfect it by means of katadyn silver contained in their walls along the water course. The necessity of preliminary liberation from the water to be sterilized of suspended matter contained in it, for the purpose of subsequent disinfection, is mentioned by W. Olszewski (9), Klinke (Breslau), Bach (Essen), Prof. V. A. Uglov (10). Degkwitz (Greiswald) and E. V. Suckling (11). Thus, in the above mentioned case the olygodynamic action of the silver does not present any exception, and a preliminary liberation from the water to be sterilized of matters in suspension is as necessary as in the case of the disinfection of drinking water by means of the ultra-violet rays, ozonization or chlorination.

Degkwitz, Greiswald, and Klinke, Breslau, state, that the newly developed silver preparation, so called "Anlassringe," possesses the property to be dissolved in grease and lipoides. It is also more easily soluble in water, i.e., it gives to the water a greater quantity of silver ions. So in the opinion of these authors this new silver combination is not only capable of disinfecting drinking water, containing a large amount of matters in suspension, but also such liquids, as blood serum milk, beer etc. Krause advises the addition of this silver preparation to the drinking water during the first days, in order to intensify the olygodynamic action of the katadyn silver and thereby to shorten the contact of the water with the katadyn, or the time of "after-action." We consider however that W. Olszewski, who records these data, is perfectly right expressing his doubts about such a universal olygodynamic action of the new silver preparation. Besides, it is expensive, apparently considerably more expensive than the katadyn silver.

EXPERIMENTAL DATA

By virtue of such an effect of suspended matter on the olygodynamic action of the silver, the study of disinfecting power of silver coated sand N 56 on the unfiltered Neva water presented great interest to us

The Neva, flowing out of the Lake Ladoga, flows into the Neva gulf. The chemical composition of this powerful river is characterized by great constancy in spite of its pollution by the sewage of such a large industrial centre as Leningrad. This fact is confirmed by a systematic analysis of its waters during scores of years. The Neva water is of a marshy origin and very slightly mineralized. Its color, according to the Lake Ladoga pattern, ranges about 40°, the titration alkalinity is about 0.5 of normal acid, the oxidizability according to Kubel is about 8 mgm. of oxigen per litre, the average of colonies on the agar in 48 hours time at 22°C. is about 350, the number of B. Coli found in 0.1 cc. of the water is about 40 percent in 1 cc. near 75 percent and in 10 cc. about 90 percent. The solid residue of the water, dried at 100°C., ranges from 50 to 70 mgm. per litre, the calcined remainder is from 23 to 39 mgm., the chlorides about 4 mgm. per litre, the sulphuric acid (SO_3) from 1 to 4 mgm., the silica (SiO_2) from 0.4 to 2.8 mgm., the ammonia (NH_3) from 0.004 to 0.26 mgm., the nitrous acid and nitric acid are absent, the ferrous oxide, and aluminium oxide together, ($Fe_2O_3 + A_2O_3$) from 1.2 to 8.7 mgm. per liter. The water of the Neva is one of the softest. Its total hardness in German degrees equals about 1.5. The Neva water always contains sediment, the amount of which usually rises in April (drifting of ice), in June and during the autumnal rains. The limpidity of the Neva water, determined in the cylinders of Henner by means of the Snellen type N 1, periodically shows a very great turbidity of raw water. During 1927 it dropped once to 9 cm., in 1928 to 12 cm., in 1929 to 10 cm., and in 1930 to 15 cm. of the water column. During the 16th and 17th of November, 1930, the weight of matter suspended in the Neva water and determined by us in a small porcelain crucible with a porous glass bottom (the crucible of the type of Nutsch) showed 5.43 mgm. of suspended matter in 1 litre of water and in July, 1931, 2.45 mgm. per liter.

In spite of these comparatively very small quantities, the suspended matters of the Neva water are of a very low specific gravity and communicate to the raw water a clearly marked and periodically intensive turbidity.

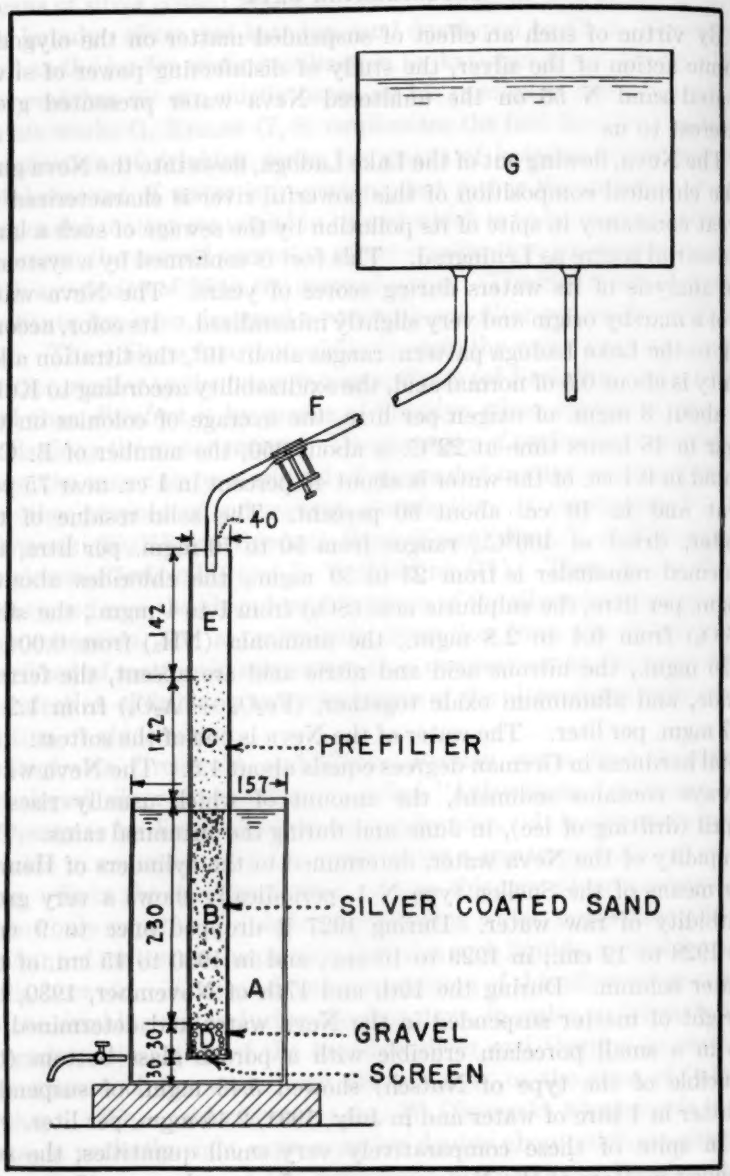

G
F
40
142
E
142
C
PREFILTER
157
230
B
SILVER COATED SAND
A
30
30
D
GRAVEL
30
SCREEN

FIG. 1

The first experimentary laboratory plant, where I carried out the investigations with unfiltered Neva water, is shown in figure 1.

The raw Neva water, with suspended matter contained in it and with the sediment dropped on the pressure tank bottom, was led to the silver coated sand N 56, having first passed through a small layer of ordinary sand. This prefilter is a necessary construction detail of our laboratory plant.

The purpose of the profilter is to enable us to use normally the laboratory plant longer than without it and to put off the moment when it is necessary to extract the sand from the plant and to wash it in water in order to remove the suspended matter that has polluted its grains.

During filtration the water level in the tube above the sand of the prefilter (C), was always kept at 140 mm. Before starting work at the installation 3 litres of water from tank A were discharged and then the actual filtration of the water from the pressure tank G began in the manner described above. It was carried on till the level of filtered water in the tank A reached its initial mark again.

During the whole of the first experimental stage (June) 3 litres of water per hour were filtered daily from 10 a.m. until 4 p.m., i.e., 6 times a day. Thus 18 litres of the Neva water were filtered daily. From 4 p.m. till 10 a.m. of the following day the experimental installation did not work, the water in it was not renewed and remained in a state of perfect rest.

Every time filtration started, the tank A was lowered to such an extent that the end of the glass tube with the prefilter and silver coated sand (B) kept in position above the tank. After finishing filtration the tube was again submerged into the tank A. By the elimination of the water pressure from below the time necessary for the filtration of 3 litres of water was reduced from 70 to 30 minutes. Later on this time limit began to increase again through the progressive pollution of the sand grains by the suspended matters and by the raw Neva water sediment.

The rate of filtration, expressed in meters per hour, proved to be a sure index of the gradual silting of sand grains. On the seventh day (after the starting of work) when 134 litres of raw Neva water had already been filtered through the glass tube of 4 cm. in diameter, filled with sand, the rate of the filtration was found out to be of 4.1 m.p.h. Gradually diminishing it dropped on June 21 to 1.8 m.p.h., with a simultaneous increase of the filtration time to 60 minutes.

By this time 284 litres of Neva water had already been filtered. The prefilter sand and the silver coated sand were taken out of the installation and washed. It was found then that the greatest part of the suspended matters and sediments was retained by the prefilter sand. This proved the practical value of the prefilter even at its slight elevation. But the silver coated sand proved to be very much polluted and silted too. In place of its former metallic lustre its grains had a dull and dirty appearance. Its wash waters were exceedingly turbid and contained a great deal of lime and floc.

An approximate calculation has shown that the prefilter and the silver coated sand retained during the first 15 days of the experiment not less then 0.7 g. or more of the suspended matter. However, both sands were easily washed and soon restored to their former appearance.

The sands washed out with water were dried and charged again. The rate of filtration increased up to 6.7 m.p.h. and the filtration time reduced to 20 minutes. On June 27 the work of the first experimental plant was finished. During June 329 litres of raw Neva water were filtered.

The conditions of the filtrate every day during the trial samples for the bacteriological analysis, were different. At 10 a.m. it remained without dilution during 18 hours. At noon, when taking the second trial sample of the filtrate for the analysis it consisted of 1 part of the initial filtrate and of 6.25 parts of the raw Neva water, filtered during the time from 10 a.m. to noon.

At 2 p.m. when taking the third trial sample for analysis the filtrate consisted of 1 part of the initial filtrate and of 39 parts of the raw Neva water, filtered from 10 a.m. to 2 p.m.

As is widely known, the oligodynamic action of silver as well as of other metals, other things being equal, depends on the time of its contact with the activated (by means of ions of silver or other metals) water. This "time factor" is usually of paramount importance.

Whereas in our experiments from the moment of stopping of filtration up to the moment of taking the filtrate trial sample for analysis, the duration time was fixed at 25 minutes maximum, usually much less than that, i.e., sometimes decreasing to 3 to 5 minutes. As a rule it did not take more than 1 hour from the moment of filtration until taking filtrate samples for the analysis, a twice shorter contact time, than in the sterilization jar of Krause (7, 8). Since tank A had remained open the whole time its water continually and inevitably

became polluted by the air microbes (by dust infection) and by other microbes from without. These microbes penetrating from without did not come into contact with the silver coated sand and could be killed only by the oligodynamic action of the activated water from the tank (filtrate). Such unfavorable conditions of the work of the experimental plant were admitted by us on purpose in order to make the results worse, which were expected from the bacteriological investigations of the filtrate.

The test samples of the filtrate taken daily at 10 a.m., at noon and at 2 p.m. were studied at once and one or two hours later the "after-action."

Bacterial results

The results of the bacteriological study of the filtrate are shown on table 1. For comparison results are given also of the sterilization of the Neva water by means of chlorine at the Main Plant of the Municipal Water Supply, where the investigations had been carried out during the experimental period.

On June 12 the rate of the filtration diminished through the clogging of the sand from 7 to 4.1 m.p.h. On the same day the water from the glass tube with the silver coated sand was filtered first into a large unsterile bottle and from the latter it was then poured into the tank A.—It was the first attempt to eliminate the upward pressure of the water and thereby to lengthen the duration of the filtration. From June 13 analogous results were obtained merely by lowering of the tank A during the filtration, as described above. This accounts for the appearance of B. Coli in the sample of the filtrate taken from 10 cc. of the water at noon and in the sample taken at 2 p.m. from 1 cc. of water. In proportion to the clogging of the sand in the filtrate sample, tried directly, more often solitary microbes appear proved by the test as cocci, diplococci, staphylococci and spore bearing bacilli. They all appear to be of air origin. At 10 hours 30 minutes on June 17 the raw Neva water of the pressure tank was artificially contaminated with B. Coli. The latter appeared in large quantities in the filtrate samples taken on the same day at noon and at 2 p.m. respectively, and at once greatly reduced the B. Coli titre of the filtrate, which effect lasted during the following two days. By that time the sand had been strongly polluted, the rate of the filtration having been reduced to 2 m.p.h. The sand on being washed out completely restored its original oligodynamic properties. The table

shows that till the silver coated sand is not greatly polluted and clogged, its bactericidal properties in efficiently sterilizing the Neva water are in no way impaired.

In the chlorinated water the number of the colonies never equalled zero, but during this period ranged from 4 to 62 colonies and on an average equalled 20 in 1 cc. of the water. As to the water of the filtrate of the experimental plant, in spite of the above mentioned conditions unfavorable to its functioning, with the exception of but one day (June 17) of its artificial contamination, in the samples tried directly, the number of the colonies varied within the ranges of 0 to 49 colonies in 1 cc. of the water, being on an average equal to 8; after one hour of additional contact it ranged from 0 to 16, with an average

TABLE 1

DATE	AMOUNT OF THE COLONIES IN 1 CC. OF NEVA WATER ON AGAR AFTER 48 HOURS						B. COLI IN 1 CC. OF NEVA WATER			
	Before chlorination	From the head tank of the experimental laboratory plant	After chlorination	Of the filtrate of the experimental laboratory plant: Immediately	After 1 hour	After 2 hours	Before chlorination	After chlorination	From the head tank of the experimental laboratory plant	Of the laboratory plant filtrate
June 6	350	290	6	0	0	0	1.0	>400.0	0.1–10.0	>100.0
June 7	570	427	10	0	0	0	10.0	>400.0	0.1–1.0	>100.0
June 8	260	310	18	1	0	0	0.01	>400.0	—	>100.0
June 9	250	145	36	0	0	0	1.0	>400.0	—	>100.0
June 11	530	295	62	0	0	0	0.01	1.0	1.0	>100.0
June 12	840	263	4	9	2	0	10.0	>400.0	1.0–10.0	1.0–>100.0
June 13	510	287	40	4	0	0	10.1	>400.0	1.0–10.0	>100.0
June 14	250	290	16	2	1	0	1.0	>400.0	1.0–10.0	>100.0
June 16	170	289	8	5	4	1	1.0	>400.0	1.0–10.0	>100.0
June 17	380	1218	30	943	706	262	1.0	>400.0	0.0001–10.0	0,01–>100.0
June 18	860	637	6	49	3	0	1.0	100.0	0.0001–0.001	0.01–>100.0
June 19	460	423	8	41	16	3	10.0	>400.0	0.01	1.0–>100.0
June 21	410	122	14	0	0	0	10.0	>400.0	10.0	>100
The experimental laboratory plant after the sand washing										
June 26	400	1083	—	0	0	0	100	100.0	0.1–1.0	>100.0
June 27	290	1683	22	1	0.3	0	100	100.0	1.0–10.0	>100.0

equal to 3, after 2 hours it ranged from 0 to 3, with an average of 0.3 colonies.

The B. coli titre of the chlorinated water in spite of the sufficient dose of the chlorine and the presence of free chlorine in the water after an adequate time of contact with the chlorine gave notwithstanding on one occasion a slip of B. coli in 1 cc. of the water and on the 18th, 26th and on the 27th of June—in 100 cc. of water. However in the filtrate of the experimental plant except on June 12 (the pollution with the bottle) and on June 17 and 19 (the artificial contamination) the B. coli was not found in 100 cc. of water. Thus we come to the conclusion that until the sand coated with silver is polluted with matters in suspension and sediment of the raw Neva water, its bactericidal effect upon the raw Neva water was greater during the said period than the sterilizing effect of chlorine at the main plant. The oligodynamic action of silver was greatly reduced only after its considerable silting by the matters in suspension. After mechanically conducted cleaning of the sand with water its oligodynamic power was completely restored. The filtration of 328 litres of the raw Neva water through 500 g. of the sand coated with silver in the tube of 4 cm. diameter not in the least diminished the bactericidal power of the sand N 56 coated with silver.

Prof. V. A. Uglov (10) filled a funnel about 30 cm. in diameter with 500 gr. of the silvered sand prepared according to his method. He sealed the top of the funnel with an absorbent cotton. The results of the filtration of 1 litre of the raw Neva water through such a funnel are given in table 2.

Prof. V. A. Uglov (10) considers the results shown on table 2 as typical of his repeated experiments. The comparison of these results with those shown on table 1 proves that the silvered sand N 56 possesses a greater oligodynamic power on the unfiltered Neva water, than the silver coated sand of Prof. V. A. Uglov.

The investigators, who had studied the oligodynamic action of metals, silver in particular, came to the conclusion, that the oligodynamic action manifests itself more strongly on the pathogenic microbes, than on the typical saprophytes, e.g., of air and water, and particularly on the spore bearing microbes. This opinion is shared in particular by R. Doerr and P. Saxl. This statement is illustrated by the summary table of Degkwitz in which the results of the experiments of Saxl, Laubenheimer, Doerr and those by Konrich (12) are given. This likewise was confirmed by the experiments of G. Krause

and Wo. Olszewski (9). The experiments of Trendtel (13) on the sterilization of fresh morning milk in the jar of Krause likewise proved a large percentage of surviving saprophytes. The experiments of Schweizer (14) with the tap water of the city of Bern showed that during the first 48 hours the quantity of the microbes in the jar of Krause even increases, beginning to die out only after 48 hours; the water contaminated with B. coli becomes free from it in the same jar after 2 hours. In the portable installation of Prof. V. A. Uglov (10) the single saprophytes were found in 1 cc. even after 10 hours of "afteraction." The experiments of Doerr proved that the resistance of the saprophytes under the effect of the oligodynamic action

TABLE 2

The experiment of V. A. Uglov with unfiltered Neva water

EXPERIMENT N1	UNFILTERED WATER	DIRECTLY AFTER FILTRATION THROUGH:		AFTER FILTRATION			RATE OF FILTRATION
		Ordinary sand	Silver coated sand	2 hours	3 hours	4 hours	
The amount of colonies in 1 cc. of raw Neva water on agar after 48 hours at 37°C.	1545	670	96	7	2	0	
The coli titre after 48 hours	0.01	0.1	>10.0	>10.0	>50.0	>50	120 cm.³ per min.
The amount of the anaerobes	5	6	6	7	7	3	

diminishes with the increase in the concentration of the activated water. If the water is not sufficiently activated, as is proved by all the investigators, the same oligodynamic effect may be reached by the adequate lengthening of the "afteraction" time.

Table 1 shows that in our experiments, in spite of the reducing of the "afteraction time" at any rate down to 30 minutes, or less (while the silvered sand N 56 was not yet very polluted and clogged by the suspended matters of the Neva water), it manifested a high oligodynamic action. The reduction of the afteraction time (equalling at the commonly accepted rates of filtration approximately to 4 to 5 m.p.h.) up to 30 minutes gives the possibility of practical application of this sand for the disinfection of drinking water in portable installa-

tions. Our experiments have at the same time confirmed the experiments of all the other investigators with regard to the necessity of a thorough preliminary liberation from the water to be sterilized of suspended matter and sediment.

Time of action

The longer the silver is in the water, the higher is its oligodynamic action. That was proved by the experiments of Egg in Basel, of Jung, of Freundlich in Berlin, of G. Krause and also by our numerous researches.

G. Krause proves in his experiments that with the shortest time of contact of water with the katadyn silver, in the filtrate, contaminated with 2,000,000 B. Coli, the microbes perished after 3 to 4 hours.

According to the data of G. Krause, with a short time of contact of the silver coated sand with water, 15 to 30 thousandths milligram of silver suffices in 1 liter of the water. A high oligodynamic power already characterized the water, containing in 1 litre 15 to 16 thousandths milligram of silver. The experiment of Charles Egg in Basel showed even that the oligodynamic action of the katadyn silver begins to manifest itself only with contents of 15 thousandths milligram of silver per 1 liter and develops completely only at 40 thousandths milligram per litre (9).

G. Krause found that during the contact of silver with water, the time was reached when the concentration of silver ions reached its limit and did not increase any more. The duration of this time was not indicated by him. We have performed along this line 40 experiments with silver coated sands NN 15, 17, 20, 22, 27, 33, 47, 55 and 64. The contact time of these experiments was 5 hours, 24 hours, 7 days, 17 days, 75 days, and 85 days. The results of these working tests did not confirm the above statement of Krause on the early reaching of the limit to water saturation with the ions of silver. To judge from the bacteriological action of the activated water our experiments have shown an increase of its oligodynamic action up to 85 days. At the same time our experiments have shown that, during the same time of contact, for instance during a month, the oligodynamic action of different silvered sands was quite different. Thus, the increase in the number of ions in the water depends on various conditions and particularly on the silver preparation itself.

Although the silver coated sand N 56, constantly submerged in

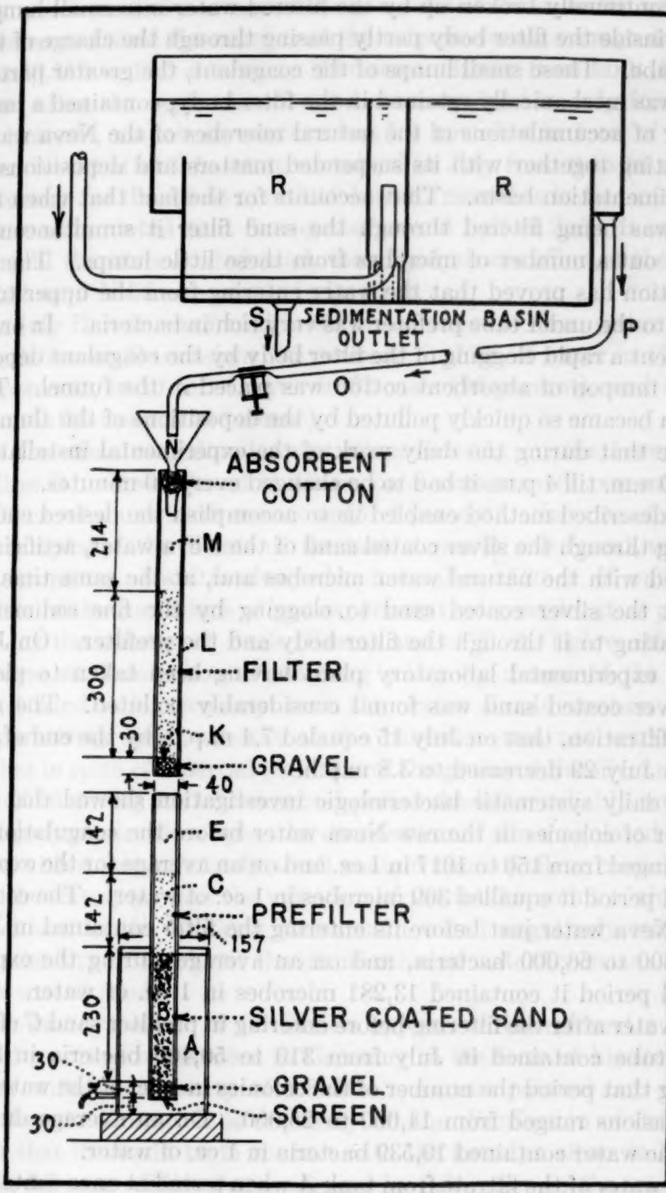
water, lost more of silver ions than the silver coated sand in the experiments of Prof. Uglov or as compared to the katadyn in the experiments of Krause, still the retention of its initial bactericidal power after the filtration of 328 litres of water was insufficient to characterize its bactericidal resistance. Our further experimental researches were intended to clear up this very important point.

The research work in July, 1931 was conducted with a view to clearing up the question of the bactericidal power of the silver coated sand N 56, when acting on the Neva water, in which the number of natural bacteria was artificially raised to a great extent. These experiments were also intended to procure supplementary experimental data to decide upon the bactericidal stability of the sand N 56.

Bactericidal stability of silvered sand

In conformity with the problems set there was a change in the experimental installation itself. It consisted, as shown on figure 2, of a sedimentation basin *RR*, a sand filter *L*, the upper tube, and a tank with a glass tube submerged in it and charged with sand, the prefilter *C*, and silver coated sand *B* taken out of the former installation. The experiments started on June 30 and were carried on until July 30. The raw Neva water was coagulated by aluminium sulfate in buckets and was poured out towards the end of the working day in a vertical sedimentation basin *RR* on the assumption, that the water level should constantly be above the upper rim of the annular wall through of the vertical sediment basin. During the daily break in the work of the installation from 4 p.m. to 10 a.m. of the following day the floc of the alumina hydrate together with the suspended matter and depositions, carried away by them, precipitated from the coagulated water on the bottom of the sedimentation basin and also on that of its annular wall. From the bottom of the latter the water was conducted by the tube *"PO"* (figure 2) through the glass funnel *N* on the sand filter *L*. The filtrate was conducted to the lower tube, filtered through the prefilter *C* and the silver coated sand *B*, and was then directed to the tank *A*. The experimental installation in July worked in the same manner as the one in June.

In spite of the entrance of the coagulated water in the upper tube from the annular wall through the sedimentation basin, no visible film was observed on the sand filter (of the upper tube) surface. This may be explained by the fact that in the process of its formation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K
GRAVEL
40
142
E
C
142
PREFILTER
157
230
SILVER COATED SAND
A
30
GRAVEL
SCREEN
30

FIG. 2

it was continually broken up by the filtered water into small lumps, carried inside the filter body partly passing through the charge of the lower tube. These small lumps of the coagulant, the greater part of which was mechanically retained in the filter body, contained a large number of accumulations of the natural microbes of the Neva water coagulating together with its suspended matters and depositions in the sedimentation basin. That accounts for the fact that when the water was being filtered through the sand filter it simultaneously washed out a number of microbes from these little lumps. The investigation has proved that the water entering from the upper tube filter into the under tube prefilter was very rich in bacteria. In order to prevent a rapid clogging of the filter body by the coagulant depositions a tampon of absorbent cotton was placed in the funnel. The tampon became so quickly polluted by the depositions of the alumina hydrate that during the daily work of the experimental installation from 10 a.m. till 4 p.m. it had to be changed every 10 minutes.

The described method enabled us to accomplish the desired end of filtering through the silver coated sand of the Neva water, artificially enriched with the natural water microbes and, at the same time, to subject the silver coated sand to clogging by the fine sediments, penetrating to it through the filter body and the prefilter. On July 29 the experimental laboratory plant having been taken to pieces the silver coated sand was found considerably polluted. The rate of the filtration, that on July 15 equaled 7.4 m.p.h. by the end of the day on July 29 decreased to 3.8 m.p.h.

The daily systematic bacteriologic investigation showed that the number of colonies in the raw Neva water before the coagulation in July ranged from 150 to 1017 in 1 cc. and on an average for the experimental period it equalled 369 microbes in 1 cc. of water. The coagulated Neva water just before its entering the filter contained in July from 300 to 66,000 bacteria, and on an average during the experimental period it contained 13,281 microbes in 1 cc. of water. The same water after the filtering before entering in prefilter sand *C* of the lower tube contained in July from 310 to 50,400 bacteria in 1 cc. During that period the number of the colonies in 1 cc. of the water on 27 occasions ranged from 14,000 to 25,000. On an average during July the water contained 10,539 bacteria in 1 cc. of water.

The water of the filtrate from tank *A* when tested at once contained during July from 0 to 124 bacteria and on an average during the experimental period 11.5 colonies in 1 cc. Thus, after a comparatively

very small time of contact of the coagulated Neva water with the silver coated sand the number of the colonies on an average dropped from 10,539 to 11.5 a month. The same filtrate from tank *A* when tested after the expiration of one hour contained in July from 0 to 119 bacteria, and on an average but 7.4 microbes in 1 cc. of water. When tested after 2 hours it contained in July from 0 to 56 and on an average for the whole month of July 3.2 microbes in 1 cc. of water. It was to be noted that during the second half of July, in spite of silting of the silver coated sand, the oligodynamic effect of the silver coated sand N 56 was particularly great.

In July B. coli was found in 0.1 cc. of the raw Neva water before coagulation on B occasions (22 percent), in 1 cc. of water in 17 cases (74 percent), in 10-cc. of water in 22 cases (96 percent), and in 100 cc. in all the cases (100 percent).

In the same coagulated water when entering on the lower tube prefilter B. coli was found in 10 cc. on 3 occasions (9 percent) and in 100 cc. of water in 18 occasions (51.4 percent). In none of all the trial samples of the filtrate of the tank *A* was B. coli found, without any exception. Its titre always has been above 100 cc. of water.

Thus in the conditions of our experiment we consider it as proved that (*a*) the opinion of Bach (Essen) and of V. A. Uglov—that for purposes of disinfection of drinking water by means of the silver coated sand it is necessary that the water should contain but a comparatively small amount of the bacteria—was not warranted; (*b*) that in spite of a partial pollution of the grains of the silver coated sand N 56 during the experimental period the latter reliably retained its oligodynamic effect upon the disinfection of the coagulated Neva water with a comparatively small contact time of silver coated sand with the water, (*c*) that the variation of the total amount of the bacteria found in the drinking water cannot itelf negatively influence the reiiability of results of the disinfection of water by means of the silver coated sand.

The katadyn silver of G. Krause appears to have found a widespread practical application in Germany in the form of his sterilizator-jar with the capacity of 1.8 litre. As was pointed out above, according to Krause, it is necessary for the disinfection of drinking water that it should be in contact with the katadyn silver in his jar during 2 hours. That was confirmed by Schweizer on the condition of the presence of 1000 B. coli in 1 cc. of water, but he found at the same time that the amount of saprophytes of the Bern tap water in

the same jar considerably increased during the first 48 hours. The experiments of Olszewski with the filtered water of the Elba confirmed the conclusions of Schweizer concerning the saprophytes and at the same time showed that for a reliable disinfecting effect the water should remain in the Krause jar for 6 hours or more, including the time of "afteraction." The experiments of Gans in Stralsund have led him to the conclusion, that the time ought not to be less than 3 to 6 hours and according to the opinion of Bruns (Gelsinkirchen), even 6 hours or more. The experiments of V. A. Uglov, who had checked the disinfecting effect of the Krause jar on the raw Neva water, warranted the conclusions by Schweizer in respect of the saprophytes, and at the same time showed that the initial titre of B. coli of the raw Neva water equalled to 0.001 cc., even after its being in the G. Krause jar during 4 hours, did not increase more than 50 cc. All these data led us to the conclusion, that the silver coated sand N 56 in the conditions of our experiments possesses a larger bactericidal power, than the katadyn silver in the Krause jar.

The comparison of the result of the oligodynamic effect of the silver coated sand N 56 under the conditions of our experiments during July of 1931 with those of the chlorination of the Neva water on the Main Leningrad Water Supply Station during the same period can be accomplished on the strength of the following practical data at hand. After a sufficient contact with the chlorine of the chlorinated water in July there remained in it about 0.07 mgm. of the free active chlorine. The amount of bacteria in the raw Neva water during the same period before the chlorination equalled 598 in 1 cc., whereas the chlorinated water entering the pipes of the water supply contained an average of 15.8 bacteria per cubic centimeter (2.6 percent). In the conditions of our experiments in the water, entering the lower tube of the prefilter, the amount of bacteria equalled on an average 10,539, whereas in the filtered water from tank *A* tested at once it equalled 11.5 bacteria (0.1 percent), after 1 hour of additional "afteraction," 7.4 (0.07 percent), and after 2 hours 3.2 microbes (0.03 percent). During the same period in the chlorinated water entering the pipes of the water supply B. coli was found but once in 100 cc. of water and in the filtrate from tank *A* even tested at once the B. coli has never been found in 100 cc. of water. We therefore conclude that the disinfection of the Neva water in July in the conditions of our experiments had more reliable results than the chlorination of the water at the Main Water Supply Station.

Concentrations of silver

On the porcelain rings of the Krause jar according to the data of V. A. Uglov, there are 0.63 percent of silver. Professor Uglov has prepared the silver coated sands with a content of 0.38, 0.46 and 0.92 percent of silver. According to the statement of the author he has not succeeded in fixing on the sand more than 1 percent of silver, by weight (10). During the experimental work on this subject we have prepared 145 different silver coated sands, containing from 0.009 to 11.6 percent of silver, by weight. There were no difficulties in the arbitrary raising of the silver content in the sand. However, the exhaustive treatment of the problem showed that the silver coated sand N 56 containing but 0.3 percent of silver, by weight, appears to satisfy the demands better than any one of our silver coated sands. Thus the sand N 56 contains by weight over 33.3 times less of metallic silver as compared with katadyn silver of G. Krause.

For the disinfection of 100 parts of water Krause used 1 part (by weight) of the katadyn silver, or 10 parts (by weight) of the katadyn sand, containing (by weight) 10 percent of the silver. The expediency of just such a weight correlation between the water and the katadyn sand was warranted by the experiments of F. Konrich (12). A number of comparative experimental researches we had carried out with different silver coating sands, various pathogenie bacteria and at different times of contact of the water with the sand, led us to the conclusions confirming those of Krause and Konrich, only in so far as the most satisfactory weight correlation between the water and and the silver sand is concerned. Our experiments have proved that the weight correlations between the water being disinfected and the metallic silver on the sand are of no import. *H* may be explained by the fact that only the top surface layer of silver, surrounding the grains of the sand, affects the disinfectant power of the silver coated sand. Thus, to disinfect a given unit weight of water not the thickness of the silver layer itself is essential, but the total of the silver coated surfaces of all the grains, which is determined by the number and the diameter of the grains. The increase of the weight of silver content augments the surface of the silver coated sand through the increase of the thickness of the silver coating to such an insignificant extent, that it practically does not influence the increase of the total silver surface of the sand grains.

The optimum weight percentage of the silver in the silver coated sand may be discovered in each individual case only by experiment.

This accounts for our charging the glass tube, only with 500 g. of the silver coated sand N 56 in 5 litres of the filtered water contained in tank *A* of our experimental laboratory plants in June and July.

From all the silver coated sands known up to the present day the katadyn silver of G. Krause is considered as the most stable. This investigator every day, during three months, passed through 500 g. of the katadyn sand 40 litres of water, containing 1 to 2 millions of B. Coli per cubic centimeter. After the close of the experiment no weakening was found of the bactericidal power of the katadyn sand (3). Such a result of the experiments undoubtedly proves a great bactericidal stability of the katadyn sand. Unfortunately Krause does not precisely show what water he experimented with, distilled or raw drinking water. The clearing up of this point would throw more light upon the problem in question and upon the results, obtained by G. Krause. The work of R. Degkwitz (15) leads to the conclusion that the experiments of Krause, which lasted several months, were performed with a distilled water and not with raw drinking water. Krause too does not indicate the rate with which the water was filtered through his katadyn sand. The ascertaining of this point is important to judge about the time during which the katadyn sand was losing the silver ions for the disinfection of the water, which in its turn must have influenced the stability of the silver coated sand. Krause likewise does not indicate whether his katadyn sand was continually submerged in the water during 3 months of his experiments as is generally the case in practical conditions of its application in life, or the katadyn sand was in contact with the water in the course of the experimental period during some hours per day only. This curcumstance in its turn may affect the stability of the silver coated sand. According to these considerations, in the practical application of the katadyn sand, different results may be obtained from those obtained by G. Krause in his experimental conditions. F. Konrich (12) and Degkwitz (15) too have experimentally confirmed the stability of the Krause katadyn sand. However, both these investigators, as well as the latter, do not specify the water they had experimented with, the rate of the filtration or the time during which the katadyn sand was in contact with the water being sterilized in the course of all the experimental period.

Capacity

Krause states that one jar can disinfect 1 million litres of water (8). Such a statement with regard to the stability of the katadyn

silver is not founded upon experiment, but only on a pure mathematical calculation. W. Olszewski (9) explains that Krause bases his assertion on the following considerations. All the porcelain rings of his jar contain 18.7 g. of the katadyn silver. For the disinfection of the water in this jar about 15 milli-milligrammes of silver per every litre of the water being disinfected is expended. But in this case Krause admits that his jar will safely disinfect the water every time during two hours up to the moment when there remained at least slight traces of the silver on the rings of his jar. But that contradicts even the data of Krause himself, who has found that for such a disinfecting action the ratio by the weight between the katadyn silver and the water should be at least equal to 1 to 100.

Just such a ratio between the katadyn silver and the water exists only in the new jar with a capacity of 1.8 litres and a little more than 18 g. of the katadyn silver. In time, the silver quantity on the rings of the jar decrease to such an extent that it will no longer have any reliable disinfecting effect. It is absolutely unknown when that time may come, especially when raw drinking water with its highly varied chemical composition and different physical properties is used.

Prof. V. A. Uglov, while using the Krause jar in his home, convinced himself that after about two years this jar began to produce a very disagreeable odor like that produced by the decomposition of organic matter. We have tested the rings from the Krause jar taken by us from Professor Uglov after his having used the jar. Our investigations have proved that the rings had lost their disinfecting power. That is why the aforesaid stability of katadyn sand claimed by Krause in his experimental conditions practically sheds no light upon the question of the bactericidal stability of his katadyn sand or on the efficiency of his jar in the aforesaid sense. Having no intention to deny the indisputably great stability of the Krause katadyn sand, I would merely like to say that there are no objective data as regards the practically limitless stability of the katadyn sand or of the katadyn silver, as claimed by Krause. This question may be cleared up only by means of the bacterial control of the sterilizing effect of the katadyn sand or of the katadyn silver when actually applied during a protracted period of time.

The stability of the silver coated sand N 56 during the months of June and July of 1931 was experimentally studied by us in the conditions analogous to those under which the sand was used to disinfect raw drinking water, the silver coated sand being constantly in the

water. The sand became polluted by the suspended matter and sediment of the raw water and of the coagulated Neva water and was periodically washed out. During June and July through the same silver coated sand N 56, 340 litres of the raw Neva water and 540 litres of the coagulated water or the total of 880 litres of water was filtered. In these conditions the bactericidal power of the silver coated sand N 56 did not decrease in the least in any one respect as compared with that at the very beginning of the experimental period.

During 1931 we continued the prolonged experiments with the same silver coated sand N 56 at the large experimental plants. Through the silver coated sand were filtered the tap water from the Neva, the raw water from the Neva, the Neva water coagulated by means of the sulfate of alumina and the mixture of Neva water and that from the river Fontanka badly polluted with sewage. Altogether, with the experiments in June and July, in the course of 5½ months 2250 litres of the above mentioned water were filtered through the silver coated sand N 56. The sand was repeatedly washed out. After the completion of the whole series of experiments, the sand was for the last time washed out in cold water. The examination of its oligodynamic effect with suspended microbes gave the following results

The control, 1,300,000 B. Coli; after 5 hours—nearly complete sterilization

The control, 1,700,000 B. typhi abdominalis; after 5 hours—complete sterilization

The control, 1,700,000 B. typhi abdominalis; after 5 hours—absolute sterilization

The control 1,000,000 B. paratyphy A; after 5 hours—absolute sterilization

The control, 2,000,000 B. paratyphy B; after 5 hours—absolute sterilization

The control, 410,000 B. Shiga; after 3 hours—absolute sterilization

The control, 500,000 V. cholerae asiaticae; after 45 minutes—absolute sterilization

Thus after 5½ months of work the silver coated sand N 56 has lost nothing of its original oligodynamic power. This sand undoubtedly possesses a strong bactericidal stability, which justifies its practical application on the small plants as well from this point of view.

COST

One cubic millimeter of katadyn silver costs 3000 marks. Kause does not state the cost of a weight unit of the katadyn silver or sand.

According to the data of Olszewski (9) it is not difficult to calculate that 1 m.[3] of katadyn silver weighs 8 kgm. and 1 kgm. of katadyn sand costs 37.5 marks.

Again the cost of the silver for 1 kgm. of the silver coated sand N 56 according to our quotation was 66 cop. Therefore our silver coated sand is incomparably cheaper than that of G. Krause, which makes it economically very profitable for the disinfection of the drinking water under widely different practical conditions and for medical purposes

The disinfection of water by means of silver completely meets all the requirements of the hygienist. It does not only denature the natural water as the boiling and chlorination do, but in no way change the physical or chemical properties of water. Therefore, from the point of view of hygiene this new method appears one of the ideal means of sterilization of drinking water.

A very important advantage of this method of water disinfection is the ability of the water, disinfected by means of silver, to become "active," i.e., to assume in its turn the disinfectant properties. Infectious bacilli, getting by chance into boiled water, do not meet any obstacles to their existence in it and can cause the corresponding infectious disease in the consumers of such water. Such cases are known in water supply practice. Again the contagious bacilli having got into the water that had been activated by the silver must perish in it, as in a disinfecting medium. The water disinfected by silver is quite harmless for the consumer. This fact is well established by the experiments upon the animals (Degkwitz (15)). One may be convinced of it also by computation, showing the amount of silver a person is able to introduce into his constitution while using the water that has been disinfected by silver. This quantity is less than that consumed by a man while using silver forks and spoons (F. Konrich (12)) or not more than the quantity of silver given off by silver stoppings in the mouth during scores of years (Degkwitz (15)). To eliminate all doubt with regard to the harmlessness of the application of the water activated by silver it is necessary to note a different case, viz., the experiments with the immediate effect of metallic wires on a living tissue, as was the case for instance with the experiments of Singer and Hoder (16). The minimum amount of silver ions in question at the oligodynamic(millimilligram per litre) is completely absorbed in the mouth cavity by the mucus and other substances found in the latter. Thus, there are no objective data to suspect the

slightest harm to a man, using the water that has been disinfected by silver. On the contrary, there is every reason to consider such water as having a salutary effect. In that respect the statement by J. Markwalder (17) is of interest.

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MEETING EMERGENCIES IN WATER WORKS

By Arthur E. Gorman

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It is the duty and obligation of every public utility to render safe, adequate and uninterrupted service to its customers. In no utility is this obligation more imperative than in water works, for on this service the health, comfort, safety and welfare of the dependent community rest. In fact, in many cities all other public utilities are in turn dependent on the public water works system. It therefore behooves every responsible water works man to prepare for emergencies which may affect his system.

Emergencies may be divided into two general groups.

1. Those resulting from so called Acts of God, and
2. Those resulting from acts of man.

The former, while generally uncontrollable, can in most cases be anticipated, allowing precautionary measures to be taken to guard against or minimize their effect on a water works system. Emergencies of the latter group are largely avoidable and when not so their effect can be weakened by proper application of forces at hand directed by a reasonable degree of intelligence.

Under acts of God the following may be listed:

Earth quakes Volcanic eruptions Tidal waves Hurricanes Cyclones Tornadoes Rain, (a) at excessives rates (b) prolonged Snows, (a) deep (b) drifts (c) crusts (d) slush Hail Lightning Thunder Winds (a) continued from same direction (b) squall Barometric pressure Floods Droughts Hot weather Cold weather Sunshine, (a) excessive (b) deficient Freezes or frost Fogs Ice, (a) surface (b) fragile (c) fields (d) packs (e) glacial

Under acts of man may be listed:

Fire Wrecks Explosions Accidents Poisoning Spills Electrocution Strikes Wars Quarantine Laws Rumor

Any one or combination of these "acts" or circumstances might strike a vital point in a water works system and put it out of com-

mission temporarily or for a continued period. In other cases an emergency might have been well provided against with a defense or proven effectiveness, only to crumble to pieces when a combination of circumstances in an order wholly unexpected, develops.

Many of these acts or circumstances are of known expectancy, occurring seasonally or as a result of some other local factor; others are rare, but in the light of past experience are possibilities and should be provided against.

For instance, we expect snow and sleet in the winter. A plant located in a northern climate and on a high hill with steep approach grades should by all means be equipped with coal, chemicals and supplies to carry it over periods when deliveries are not possible. Likewise, a water plant located within the flood stages of a nearby stream should be protected against high water by proper dikes. Failure to take these elementary precautions is nothing short of negligence for which water works officials are and should be responsible.

Contrasted with these cases let us cite an example of the other extreme, namely, where in spite of unusual precautions an emergency develops which was wholly unexpected. Illustrations of this kind are not easy to make. The breaking of both duplicate pipe lines to a city from a water plant, due to an earthquake, would be an illustration. In between these extremes there are countless numbers of possibilities which might cause an acute emergency to develop at any water works, all depending on the characteristics of the system.

The source of supply for a water system is obviously its most important unit. It must be protected and safeguarded against the most extreme type of a possible emergency. Sources of supply are usually of three types: (1) impounded surface supplies, such as lakes and reservoirs; (2) running streams or rivers; (3) underground wells or springs. Each has its vulnerable points, depending on local circumstances, and the geographical location of the source. Most points of weakness or danger can be anticipated by reasonable study and can be safeguarded against by intelligence and alertness.

For example, if a water works has as its source of supply a large river, it is the duty of the water works official to study the characteristics of the river—its flow and flood factors, contributing sources of pollution, its turbidity after rains, possibilities of ice jams, biological activity in pools, low water influences, types of industries up stream from the intake and the character of their wastes. Much of these data are available on request from proper governmental agencies.

Similarly, a water works having an impounding reservoir or natural lake as a source of supply should know its characteristic changes following periods of heavy rain or drought. It should keep posted as to temperature of the water and the effect of the spring and fall turnover. It should know what sources of pollution exist on the water shed; the health of inhabitants living on the watershed; the effect of ice in winter. If the lake is long and narrow it may be subject to severe changes in elevation and bottom disturbances, due to continued high winds from one direction—the "seiche" phenomenon. The seasonal characteristics of algae and other biologic growths in the lake waters should be known. Should construction work of any character be started on or near the water shed it is the obvious duty of a water works official to investigate its possible effect on the water.

Suppose the lake is in the south and a part of the contributing water shed is a mosquito breeding marsh, and a proposal is made to stop mosquito breeding by Paris Green treatment spread from an airplane. Obviously it is the duty of the water works official to keep himself posted as to such a development and act to stop the work before this poison can affect this water supply. There are countless other examples which might be cited but these will illustrate the point that alertness is a part of the water works official's job.

If the source of supply is a deep well, it is the duty of the water works officials to know the characteristics of the substrata through which the well passes. He should know the characteristics of the water bearing strata. He should keep himself posted on all other wells driven in the immediate and even distant territory. He should see that abandoned wells are properly sealed. In short, no opportunity should be overlooked which will better prepare him to safeguard these sources of water. He cannot hide behind the alibi that conditions in this hidden source of supply were beyond his knowledge and control. He *must* show that he made a reasonable effort to anticipate emergencies. There is a circle of risks around every underground source of water supply. In the light of our history of pollution of public water supplies from such sources every one should be safeguarded by chlorination.

After the source of supply comes the delivery system to the city, with possible supplemental storage. In many systems a purification plant will exist between the collecting and supply systems. Following the supply system is the distribution and consumer service systems. There are vulnerable points all along the line which the

water works official must seek to strengthen. Duplication of vital services such as conduits, basins, filters, chlorination, pumps, power units, etc. are obvious necessities in every water works system. The degree of duplication and reasonable outlay of funds to provide this service and equipment must, of course, be governed by local conditions. But let it not be argued that a water works without reasonable equipment and personnel to meet emergencies is discharging its duty and obligations to the public.

It is probable that the perfect water works will never be built. The system which approaches perfection will be a costly one in comparison with others of its size. But this does not mean that an effort should not be made toward this end. With reasonable funds available, efficient design, careful construction and conscientious and capable operation, the average water works should be able to meet its obligations to even a severe and critical public.

The promoters or directors of a new water works system have an obligation to the public to provide proper funds for a satisfactory plant. The consulting or designing engineer has an obligation to these officials to design along sound engineering lines; this obligation should go so far as to refuse to be associated with a project which cannot hope to meet severe demands for public safety and welfare. Should circumstances require some compromise with desirable practice the consultant or designer should make clear any weak points in the system in a way as to leave no doubts as to responsibilities. A plant operating executive has a right to know the weak links in his system before he assumes charge. Afterward it is his responsibility to see that all possible is done to fortify these defects apparent or potential. A man who undertakes to operate a water works system which, beyond a reasonable doubt, is subject to breakdown jeopardizing life and property, is a simpleton who risks his reputation, his life and his self respect.

CHECKS AGAINST FAULTY DESIGN

Fortunately, we have in this country three important public checks against faulty water works design. From the standpoint of water service there is the Board of Fire Underwriters. A public or private water system not meeting the standards of this board will find its consumers penalized in insurance rates. Usually the penalties are greater than the cost of financing reasonable water works improvements. In the interests of public health we have in most states

divisions of sanitary engineering in the departments of public health which must approve designs for new or improvements in existing water works systems. Occasionally the recommendations of these two offices are in conflict on certain points, but usually the conflict pertains to general policies, which in local cases can be adjusted to the satisfaction of all. Cross connections, plant by-passes and emergency supplies are points in question.

Reliable consulting engineers are familiar with the minimum requirements of the fire underwriters and state sanitary engineers and serious controversies on matters of policy are rare. The alert water works operating official will do much to better himself and his system to seek the advice and confidence of these two advisory groups, especially in regard to the weak points in his system and how they may be strengthened. On request excellent coöperation may be obtained by this method.

AN EMERGENCY OR RISK INVENTORY

On his own and in coöperation with others, a responsible water works operator should take an "emergency" or "risk" inventory of his entire system. He should have a map of his system with these weak links clearly indicated. This map should be conspicuously posted at operating points and employes should be familiar with it. The responsible operator should develop a program for meeting emergencies when these weak points are threatened. Employes should be instructed in their duties at times of emergencies. Rehearsals of emergency requirements should be held from time to time. Instructions should be in writing, clearly and briefly prepared. They should be brought to date and revised in the light of new conditions and developments locally and elsewhere. Arrangements for emergency coöperation between the water works, fire underwriters, state board of health, local departments and other utilities in a way to assist the water works, should be made. A close friendly coöperative liason of this character will do much to safeguard a public water works system and to make the night's rest of a conscientious operating executive more peaceful.

EXAMPLES OF DIFFICULTIES

Getting back to cases again, in Illinois we have had our share of emergencies, resulting from acts of God and man. I shall cite several based on information obtained from the state department of public health. The tornado in the southern section of the state in

1925 is well remembered by most of us. At Murphysboro many small service pipes were broken off in wrecked buildings and a serious drop in pressures resulted. Several small fires broke out which had to be fought by bucket brigades. Wreckage in the streets made it difficult for water works employes to locate shut off boxes at the curbs. Although a record map of all valves, mains and shut off connections would not have prevented this difficulty at Murphysboro, it is obvious that a town which has been wrecked as that one was would be in a most helpless condition without a complete map.

During the Chicago fire thousands of service connections of lead were melted off and a tremendous loss of water resulted. Water department records were destroyed and it was years before accurate information pertaining to services was again available. The destruction of Chicago's records during this fire emphasizes the desirability of keeping water records in fire proof vaults. A copy of important records kept in some state record file would be a worth while practice for any water works to follow.

During the summer of 1928 a collecting reservoir at Marseilles was struck by lightning. No visible defect above ground was noted except a strain on the wall. Nevertheless, the lightning caused a crack in the wall of the reservoir below ground which in the following January permitted polluted water from an adjoining power canal to enter the reservoir. At the time the water level in the canal was high, due to an ice jam, while the water in the reservoir was unusually low due to an increased demand on the water system during a cold spell, when general wastage of water to prevent plumbing fixtures from freezing was practiced. Thus a combination of lightning in summer followed six months later by an ice jam and freezing weather caused an outbreak of diarrhea affecting several hundred citizens.

The 1930–31 drought created serious water shortages in southern Illinois where surface waters are depended on for public water supplies. The experience of Illinois cities, as well as thousands of others in this country, during this drought taught water works officials some long to be remembered lessons in emergency procedures. Greater impounding reservoir capacity is an obvious need. How many cities have as yet acted to supplement their system in this regard, or to reduce excessive water consumption through metering? The drought period with low water stages, continuous sunshine and increased water temperatures caused prolific algae growths in reservoirs, with resulting tastes and odors in the water. Water quality was compromised by the use of supplemental sources of supply exposed to

serious pollution. These experiences in thousands of water works throughout the United States should have taught every water works official the need and the wisdom of owning an emergency chlorinator and keeping on hand in safe storage a supply of activated carbon, copper sulphate and chlorine—the latter either as a gas or a non-deteriorating compound such as H. T. H. or Perchloron.

Jacksonville may be cited as an Illinois city which, by taking a tip from an emergency in 1926, avoided what may have been a disastrous water shortage during the drought period of 1930–31. By a strange paradox the first emergency was due to excess rain which taught a lesson which saved the day during a future drought. In 1926 as a result of 5.51 inches of rainfull in 15 hours, followed by additional rain totaling 10.83 inches in a week, the water works dam broke, releasing most of the stored water, and making it necessary to resort to a lake in a park on the water shed. When the dam was reconstructed its crest was raised, so that when the 1930–31 drought occurred an additional supply of water was on hand. Even with this extra water in storage, before the drought period was over the city had to resort to some abandoned wells.

An unusual man made emergency developed in Springfield in 1926, an emergency caused by a rumor. During the same period of excessive rainfall which caused the washout of the Jacksonville dam a rumor was started in Springfield that the water works dam at Decatur had broken and that a wall of flood water tearing down the Sagaman River valley which would in a few hours flood out the entire water works at Springfield. As the rumor spread like a prairie fire from house to house, consumers started filling bath tubs and all sorts of containers to have a supply of water to carry them over the threatened emergency. The result was a sudden and heavy demand of water which placed a very heavy load on the pumping plant. The pumpage rate during these hours was, I am told, the highest in the history of the Springfield water works. Fortunately the system had the capacity to meet this excessive demand. A less well equipped plant might have had an acute shortage of water requiring operation of filters at an excessive rate to maintain service and possibly allowing polluted water to be pumped to the system.

In Chicago continued winds from the south or southeast usually mean increased pollution of the water near our southerly cribs because of the drift of grossly polluted waters from the Indiana Harbor northward. If this occurs when ice fields have recently broken up, the degree of pollution is usually greater because sewage and indus-

trial wastes frozen in the ice as it covered Indiana Harbor are then carried forward in the fast drifting ice, without the usual diffusion which would occur if the harbor waters drifted into the open lake. This combination of circumstances, coupled with a low lake level, caused the serious pollution and taste in Chicago's water supply last December. Excess rainfall is always a danger signal in Chicago because of possible reversal of the Chicago and Calumet rivers. It calls automatically for an increase in the amount of chlorine used, because of possible river reversals and also because of the possibility of overtaxed sewers leaking into nearby tunnel shafts. Chicago has a most elaborate system of watching the weather in safeguarding its water supply. It has tided us over some very severe emergency periods.

In many smaller water works in this country an elevated reservoir will be found immediately adjacent to a water pumping station, storage reservoir or a treatment plant. Suppose this tank is blown over during a heavy wind storm? It might destroy the reservoir, break an important water conduit or destroy the pumping equipment. While in Florida in the fall of 1926 on emergency service following the first hurricane, the writer saw several water plants with important operating units out of service due to damage by wrecked elevated storage tanks.

I could cite scores of similar emergencies at water works in this country and these could be multiplied many times by the experience of other water works officials. But as I close the points I want to leave with the water works men at this meeting are:

1. Employ competent engineers to design your water works system.
2. Keep accurate maps and diagrams of the entire system.
3. Obtain the assistance of the fire underwriters and your state sanitary engineering division in locating the weak points in your system.
4. Organize your department to function promptly and efficiently in case of emergency.
5. Be continuously on the lookout for emergencies, keeping a careful watch on the weather.
6. Enlist the friendly coöperation of all other persons and agencies in your neighborhood who might assist you in emergency periods.
7. Continuously seek to strengthen every vulnerable point in your system.

(Presented before the Illinois Section meeting, April 19, 1933.)

THE GRAND RAPIDS WATER SYSTEM

By Carl H. Grinnell

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The entire water supply of Grand Rapids is obtained from the Grand River which has a drainage area of about 4600 square miles. While many other municipalities along the Grand take their supply from wells, it has been found that the supply taken from the river may be softened and filtered so that the water delivered to the consumer is uniformly clear, palatable, soft for both domestic and industrial uses, free from bacterial pollution, color, taste, and odor. Temperatures range from 32 to 82 degrees Fahrenheit, due to seasonal temperature changes.

The municipal water works supplies water to practically all built-up territory within the city limits and to some of the suburbs. The original works were built in 1874, at which time only raw river water was supplied for fire protection and lawn sprinkling, but was not suitable for drinking purposes. In 1899 a study was made to determine the best plan for procuring pure water for the City of Grand Rapids. Among the possible sources which were considered at this time were Bailey Springs, Lake Michigan, Little Muskegon River above Newago, Muskegon River near Hersey, a series of small lakes northeast of the city in Kent County, water from driven wells, Thornapple River, and Grand River. Comparatively little study was required to eliminate all other sources of supply in favor of Grand River. There was, however, an economic problem involved and little progress was made for a period of a few years.

As previously stated, until 1913 the water supplied by the municipal works was not used for drinking. Private, driven wells were used to supply the drinking water. An early competitor of the municipal water works was known as the Grand Rapids Hydraulic Company. Its supply was taken from shallow wells along Grand River. Their franchise called for the delivery of pure water to its consumers, but about 1910 the State Board of Health made some

investigations and found cases of typhoid originating in localities where this supply was used. At this time the matter of an adequate, pure water supply for the city was realized to be of the utmost importance. The economic problem still existed, but the Board of Public Works, because of the health problem involved, decided to present to the people the necessity of raising these funds. Two propositions were considered; one, to build a filtration and treatment plant—the other, to bring water through a pipe line from Lake Michigan which is some thirty miles distant.

After much investigation and discussion it was decided to build a filtration and treatment plant. This plant was completed in late 1912 and was in operation early in 1913. At this time the Grand Rapids Hydraulic Company was taken over by the city and its distribution system cross connected with that of the city for delivery of treated water. It is a fact of considerable importance that since the installation of the filtration plant typhoid has been greatly reduced and the only cases were those contracted through using water outside the city supply.

The average water demand at the present is 15 m.g.d. to supply 175,000 persons. The maximum hourly demand is approximately at the rate of 60 m.g.d. and the maximum daily usage is approximately 35 million gallons. The present filter plant unit has been developed to its intended limit with fifteen rapid sand filters having a capacity of 2 m.g.d. each and five filters with a capacity of 2.225 m.g.d. each.

The Filtration Plant intake is in the east concrete wall confining the Grand River, water flowing about 650 feet through an older 48-inch and a new 60-inch reinforced concrete conduits. These supply water to the low lift pumps under a slight head. These low lift pumps take their suction from both intake conduits which are joined together in the plant and deliver water to the mixing chambers, the coagulation basins, and the filters. Water from the clear water basin flows by gravity through a 48- and a 60-inch reinforced concrete conduit to the Coldbrook Street Pumping Station, a distance of 2500 feet.

PUMPING STATION

The low lift pumping equipment is divided into two groups, the south group consisting of three 8 million and two 4 million gallon Buffalo centrifugal pumps, direct connected by vertical shafts to induction motors. The north group consists of three 10 million and

one 5 million gallon Morris and one 5 million gallon Worthington centrifugal pumps similarly connected to motors. Current for operation is 2300-volt supplied from the municipal pumping and generating plant by two duplicate underground circuits. The total connected load at the filtration plant is 831.5 kw. while the maximum observed load is 300 kw. The four coagulation basins have a total capacity of 5.325 gallons and the clear water basins have a total capacity of 8.952 million gallons. The 48- and 60-inch reinforced conduits extending from the clear wells to the surge chamber at the pumping station are 2600 and 2800 feet long and have capacities of 36 and 50 million gallons per day, respectively.

The Coldbrook high service pumping and lighting station is located about a half mile south of the filtration plant. This station was built in 1909–1910 and contains the municipal lighting plant as well as the pumping station. This is a steam plant, bituminous coal being burned in underfeed stokers under two 509 h.p. and two 350 h.p. boilers. Steam pressure is 150 pounds. The discharge headers for both the high and low system are 48-inch cast iron mains with connections from each pump to each header and the valves are mechanically operated. The headers are in a concrete pipe gallery accessible from the pumping station.

The high lift pumping equipment consists of two Allis-Chalmers vertical, triple expansion condensing, flywheel, triplex, single acting units which were installed in 1910 and 1914, having a rated capacity of 12 m.g.d. each at 110 to 115 pounds water pressure. Also an Allis-Chalmers single stage centrifugal pump with a capacity of 15 m.g.d. against 79 pounds. This pump is driven through reduction gears by a 620 h.p. Allis-Chalmers steam turbine and is normally connected to the low service header. This unit was installed in 1924, which was followed in 1926 by the addition of a 15 m.g.d. DeLaval single stage pump operating against 75 pounds to the low with a booster pump coupled to the same shaft through which full capacity may be delivered to the high service at 125 pounds. This pump is connected through reduction gears to a 935 h.p. DeLaval steam turbine. A Worthington double pump installed in 1931 consists of two single stage centrifugals, connected by a common shaft through reduction gears to a 1050 h.p. General Electric steam turbine. This pump is designed to deliver 25 m.g.d. at 82 pounds pressure to the low service or 15 m.g. at 124 pounds to the high service by connecting the pumps in series. The normal operation of this unit is to deliver at

about an eleven million gallon rate to the low service at 70 pounds and about a ten million gallon rate to the high service at 110 pounds by dividing the flow in the discharge line from the first pump. This is accomplished by push button operated, remote controlled, electrically operated valves. While this idea may not be new, the writer knows of no other plant using this particular hook-up for water works purposes. It makes operation very easy and convenient also making it possible to keep well up on the efficiency curve of the pumps under the varying requirements of our load demand.

The estimated population of Grand Rapids is about 175,000. The city is an important manufacturing and distributing center, the principals being furniture and wood industries, foundries, machine shops, automobile manufacture, also printing and binding. The City has an area of 23.4 square miles and lies on both sides of the Grand River. The district along the river is level, but rises rapidly to the eastward to a residential district. The west side of the river is low level with a range of hills to the extreme west. Elevations throughout the city range from 14.49 to 212.49 above the city datum which is 589.01 feet above mean sea level.

BOOSTER STATIONS

The distribution system is separated by checks and closed valves into two services known as the "high system" and the "low system" previously referred to when describing the pumping equipment. The high system has two 1.5 million gallon standpipes and one 898,000 gallon standpipe. There is an open reservoir of 6.462 million gallon capacity on the low system and is used as an equalizer as these pumps are often used intermittently while pumps are run continuously on the high system because of the small capacity of standpipes.

The peak load on the system is occasioned by lawn sprinkling and usually occurs between the hours of 5 and 9 in the evening during the hot, dry summer weather. This peak demand is about four times that of normal winter demand. In order to give proper service in the outlying residental districts during the peak loads, four booster stations have been installed and are known as Booster Stations A, B, C, and D. These stations help to boost the water along in the absence of sufficiently large trunk mains for the peak loads. Some of the districts so helped are as much as five and six miles from the pumping station and the cost of installing additional large trunk mains at this time was prohibitive.

Booster Station A located at Fuller Avenue and Innes street was put in service in 1925. This station is operated by remote control from the main pumping station during periods of heavy demand to maintain the proper water level in two standpipes in the south-eastern part of the city, pumping around a check valve in a 24-inch main, it is started when the high service pressure at the main station rises to a point between 120 and 130 pounds and its operation causes a drop of about 10 pounds at the main station. One ten million gallon centrifugal pump designed to operate against a 110-pound head is directly connected to 200 h.p. electric motor. Operating in parallel with Booster A is Booster C located at Lafayette Avenue and Crescent Street. This station was built in 1930–1931. There is one 5,040,000 gallon centrifugal pump, head 27 pounds, with 150 h.p., 2300-volt motor, which pumps around a check in the 16-inch high service main in Lafayette Avenue, serving to the south central part of the high service. Booster C is operated by remote control from the main station at time of peak load and when deemed necessary; operation drops pumping station pressure to 5 pounds.

Booster Station B, located at Eleventh Street and Garfield Avenue was built in 1927 to supply the high service in the hill district in the western portion of the city, pumping around a check valve in a 10-inch low service line. There are two 1,008,000 gallon centrifugal pumps with 60 h.p., 2200-volt motors. One starts when the high service drops to 80 pounds and the other when it drops to 75 pounds.

Booster Station D, put in service in 1933, is located at Godfrey Avenue and Hall Street. Two 5,400,000 gallon centrifugal pumps, each designed to operate against a head of 70 pounds and are direct connected to 200 h.p. electric motors. Suction is from the 24-inch low service main on Godfrey Avenue and discharges into the 24-inch high service main in Hall Street which serves the south east and south districts. This station is also remote controlled from the main station by push button control. All booster stations are operated to maintain proper standpipe levels except Booster B which is automatic and is started and stopped by water pressure.

Shortly after the installation of the Filter Plant in 1913 it was noted that incrustation of mains was taking place. While it did not cause much concern at first it took on proportions as the years went by and showed this to be a real problem in the distribution system. Not only did this incrustation prevent the easy operation of valves, but also increased the friction loss of water in the transmission mains

to such an extent that their capacity was noticeably diminished, especially during peak loads. This incrustation was caused by an unstable condition of the water during cold weather. In order to complete the chemical reaction in the filter plant and prevent further incrustation, a gas plant was built in 1930 to produce carbon dioxide for re-carbonation of the water. Since the installation of this plant there has been no further depositing of lime in the mains and it is hoped that in a period of years the deposit already formed will gradually be eliminated.

Looking to the proper development of the Grand Rapids Water Works, that an adequate supply of good water may be delivered for the city's domestic, industrial, and fire protection purposes, a program for development over a period of years has been laid out. This includes filter plant additions, additional equipment at the pumping station, storage, trunk mains, and distribution mains. In line with the National Industrial Recovery Act, Public Works Program, a conservative program of about $750,000 was presented to our city commission for their approval before requesting a Government loan. The city commission approved eleven of the fourteen projects. One of the most important of the projects is a headhouse for the filter plant which will complete the present plant. There is also a boiler and a steam exciter for the pumping station and an elevated storage tank for the west hill district, together with transmission mains.

These projects along with additions from year to year made out of the income will continue to make it possible for the Grand Rapids Water Works to give its consumers a pure, soft, sparkling water in ample quantities.

(Presented before the Central State Section meeting, September 22, 1933.)

THE RICHMOND, VIRGINIA, FILTER PLANT

By Marsden C. Smith

(*Engineer, Bureau of Water and Electricity, Richmond, Va.*)

The James River, having a drainage area of 6,670 square miles above Richmond and an average flow of approximately 7,000 c.f.s., is the source of supply. This stream is typical, in its chemical character, of most streams along the Middle and South Atlantic Seaboard; which rising in the mountains pass through the Piedmont section and thence through tidewater to the Atlantic Ocean. The main chemical constituent is calcium bicarbonate with but little manganese or iron. Bacteriologically, at Richmond the stream is only moderately polluted, the nearest city of size being some 150 miles up stream. There are two distributing elements, however, that render the supply most difficult to treat: one natural, being due to wide variations in the soil of different parts of the watershed; the other artificial, being due to the discharge of waste chemicals from several paper mills located on the stream. These chemicals are most complex and persistent, and are especially objectionable because of inhibiting coagulation. Before the improvements in the physical and chemical operations of the plant, and the reduction in the quantities of waste liquors obtained, frequently no amount of coagulant could prevent a complete collapse of coagulation.

TREATMENT PLANT

The river water first enters by gravity two settling basins of approximately 150 million gallons total capacity. Here gravity subsidence of much of the heavier turbidity is obtained and the only chemical treatment used is copper-sulphate, for the control of organic growths. During the past several years a marked improvement in the control of growths has been obtained with even less use of this chemical by continuing the treatment during winter months rather than waiting for growths to appear, as was the former practice.

Passing from the settling basins the water enters a conduit approximately 400 feet long. During periods of low water the river levels were often so reduced as to limit the quantity of water avail-

able to a dangerous point. By the installation of a very novel low-lift pump to raise the water from the settling basins into the raw water conduit, at absolutely controlled levels, this difficulty was eliminated. This pump may be operated at any head from 6 inches to 6 feet total lift (1200 percent variation) at any quantity from 6 to to 52 m.g.d. with a remarkable efficiency at all useful operating conditions. The water level in the raw water conduit is under the control of the operator in the plant, being obtained by electric remote control operating on the pump when used or the control gate when river levels are sufficient to produce the desired head.

Prechlorination

At the entrance of the raw water conduit prechlorination is used in quantities varying from 10 to 20 pounds per million gallons. This treatment serves two important purposes, since sterilization is obtained at all times before the water reaches the filters, thus reducing the organic loading and relieving the filters of the responsibility of bacterial reduction. And also, it is of great assistance in coagulation, probably due to the oxidation and consequent breaking down of the inhibiting colloids and organic materials, particularly the paper trade wastes. No chlorinous tastes are produced, if the quantity of chlorine applied is maintained in excess of 10 pounds per million gallons. When melting ice or snow is in the river, a decided medicinal, metallic or chlorinous taste/odor is always present; however, this is not produced or apparently affected by the prechlorination. Many other benefits are derived from prechlorination, among which is the stabilization of the settled material in the coagulated water settling basins. It is certainly a fact that with warm waters this is indeed a most important feature, because these settled materials are often an active producer of taste/color. When basins are left too long in service, either from necessity or bad management, prechlorination is not effective in stabilization. Activated carbon will stabilize these materials over a greater range in time and putrescibility than will prechlorination.

Coagulation

Coagulation studies, not yet complete, although in progress since 1928, have demonstrated that a sudden change in pH just before the application of the coagulant, even though slight, produces a marked improvement in the efficiency of coagulation. However,

this change in pH varies with the quality of the water, requiring alkaline addition at times, acid at others. Hence, the next treatment after prechlorination is the addition of small quantities of lime or acid, rarely exceeding 10 pounds per million gallons. When acid is required CO_2 is more desirable esthetically, and but for its cost would be preferable. This reversing pH change should warn those who use pre-aeration; as the reduction of CO_2 thereby obtained may prove an expensive result.

Then follows, almost immediately, the introduction of the coagulant, sulphate of alumina. To assist in obtaining the optimum pH for coagulation, with the coöperation of the manufacturers of the material, alum of relatively high basicity and also of acidity have been tried. The limits set by the physical changes in the alum proved this of little or no value.

The treated water then enters the raw water meters by means of which the quantity of water being treated is determined, and then through the mixing chambers. These are of the conventional around-the-end type with over-and-under baffles, having a retention of 10 minutes at rated capacity of 30 m.g.d.

Following the mixing chambers are the coagulated water settling basins, four in number, having a retention of 16 hours at rated capacity when all in service. At the entrance of these basins are the mechanical devices which have been named flocculators. These machines have been described in several papers, among which are two by the writer. One appeared in the April, 1932, issue of the Water Works and Sewerage magazine; the other, presented before the North Carolina Section of this Association. Briefly, each machine consists of four horizontal shafts, set at right angles to the flow of the water, to which are attached wooden paddles. They are caused to rotate in the same direction so that the upper stratum of water is moved forward and that stratum near the basin floor backward toward the intake. This causes a recirculation of a part of the settled floc and turbidity, which is added to the incoming treated water. Also, due to adjoining paddles, along shaft levels, moving in opposite directions, a splendid mixing effect is obtained. Each machine is driven by a separate variable speed electric motor; and hence by changing the number of basins in service both the time and intensity of mechanical treatment is under control. The present installation gives a retention of seventy minutes at rated capacity when all basins are in service.

The results obtained have also been previously reported. They continue to cause a marked saving in alum required, improved effluent, increased filter runs, and make possible the use of coarser sand than was formerly possible and to operate at very small cost. Recent statements by Enslow, Baylis and others support the writer's belief that in many plants much more attention should be given the mechanical treatment of the water after application of the coagulant than has been done in the past.

Filters

Passing from the coagulated water settling basins, the water then enters the filters. However, when objectionable tastes/odors are present, activated carbon is continuously applied just before the water passes onto the filters. Much experimental work has been done at this plant to determine the most effective use of this splendid material. While many may differ, we have found that within limits, when water is filtered through the carbon rather than the carbon mixed in the water, only about one-tenth as much is required for the same taste/odor removal. When carbon is continuously fed directly onto the filters it is inevitable that there will be a reduction in the filter runs. Hence for this reason alone there is practical limit to the quantity that may be thus applied, and if this quantity is insufficient for the purposes used, then the overdose must be applied ahead of coagulation to be settled out with the coagulant, thus prevented from reaching the filters.

Recent tests prove that the most economical method of obtaining this filtering through the carbon is by coating the filter with the necessary quantity at the beginning of a run, adding more if required later in the run. The advantage of this is evident when it is considered that at a constant, continuous rate of feed of the carbon, if at the beginning of a run there is to be nearly enough, there must be vastly more carbon than necessary on the filter at the end of the run. At the time this is written the plant feed is being changed to permit this being done.

There are no doubt factors other than the reduction of filter runs that may make it advisable to feed the carbon before or with the coagulant. Many of these factors have been suggested by Stuart and others in previous articles. Close study and accurate measurement of the results obtained in the use of activated carbon at Richmond have conclusively proven two definite facts, first, that the carbon

feed should be so arranged that controlled quantities may be applied either directly onto the filters or before or with the coagulant or both; second, that an accurate study of conditions at each plant and under different water conditions must be made to determine the most economical quantities and place of application.

The Richmond filters are ten in number, and each filter area is 1078 square feet. The sand used has an effective size of 0.44 mm. and a uniformity coefficient of 1.45, and is approximately two feet in depth under which is a layer of gravel 16 inches thick. We are now conducting most interesting experiments with the filters, having replaced the sand in one of them with new sand of 0.65 mm. size and 1.47 uniformity coefficient, and none smaller than 0.5 mm. While these tests have not yet been continued a sufficient time to produce sufficient data for final determinations, it is already evident that the use of larger sand, as has been suggested by many competent men, has material advantages, but the importance of preparation of the water for filtration is vastly increased.

Certain it is that a poorly prepared water throws such a burden on the filters that for a successful effluent, the filtering rate, sand size and filter operation must be adjusted to compensate for this deficiency in preparation.

A forceful demonstration of this fact was obtained during the summer of 1929. It was desired to use the ammonia-chlorine process for the after plant protection realized so badly needed. Due to the question raised by some observers, that disinfection by this process was delayed, it was thought best to produce the chloramines before filtration. At this time, the flocculators and other improvements in plant and river water had not been obtained, and so, the preparation for filtration was rather inadequate. For this reason the filters were most carefully operated and were made to approach, as nearly as possible, the character of slow sand filters. When the persistent chloramines were introduced, within a few hours the carefully preserved mat and organic loading on the filters was destroyed with terrifying tastes/odors. With this loss went most of the ability of the filters to remove turbidity and color, and the ammonia-chlorine had to be discontinued. Careful treatment soon restored to the filters their former character, and the effluent became normal. Many additional proofs can be given from this plant's operation that poorly prepared water onto the filters, requires filters of relatively fine sand, carefully handled.

Chloramines

Since prechlorination in quantities sufficient to completely sterilize the water before filtration was being used for other reasons, as previously mentioned, it was entirely safe to form the chloramines after filtration. This was done, but other difficulties were then encountered. The introduction of the chloramines into the distribution system, the mains being heavily coated with deposits of years of service, produced intolerable tastes/odors. This difficulty was eliminated by an extremely gradual introduction of the process. Post chlorination had been used for years in quantities sufficient to hold a residual at the plant effluent of approximately 0.2 p.p.m. With this unchanged, 0.1 pound of ammonia in twenty million gallons was added, and at intervals of several days this quantity was increased by the same amount. When the plant residual had increased to the predetermined value of 0.4 p.p.m., due to the greater persistence of the chloramines, the quantity of chlorine was gradually reduced, as the quantity of ammonia was increased, until the most economical ratio was obtained to give the desired residual. This was so gradually accomplished that three months were required to obtain full operation. Thus the action of the process in the distribution system was so gradually increased that, even with trained observers spread over the system, only one slight area produced complaint, and that for only one day. The experience of the Richmond plant indicates that as a means of eliminating the tastes/odors there obtained, the ammonia-chlorine process has little or no value. There are many ways, however, that it is of great value in plant operation. As a means of protecting the open reservoir and the distribution system, the process is splendid. It has practically eliminated chlorinous tastes, even with residuals carried throughout most of the system. With the improved filter effluent obtained from improved coagulation this process has practically eliminated dead end complaints, formerly so numerous and justified, thus saving not only complaints but expensive flushing. A further value is as an emergency means of cleaning the filter beds. During the summer and fall months, runs were often reduced to six or eight hours, even before the use of activated carbon. No quantity of chlorine that we were able to apply would satisfy the demand of the clogging materials; but by the ammonia-chlorine process, the filters are now restored to normal operation in about six hours. Of course, when this cleaning is done it is necessary to waste the filter effluent through the rewash, as the tastes/odors produced during the cleaning process are terrible.

Aeration

After the formation of chloramines, the water is then aerated. This serves the two fold purposes of releasing CO_2, thereby reducing the quantity of pH correcting lime required, and producing the usual benefits of aerating river waters. Finally, lime is added for pH control to prevent corrosion in cold water pipes. This is regulated to hold a phenolphthalein alkalinity of 1 p.p.m., which has been found to be best suited for the general purposes for which the water is used in the city.

(Presented before the Southeastern Section meeting, April 5, 1933.)

THE NEW WATER PURIFICATION PLANT AT OTTUMWA, IOWA

By Horace A. Brown
(*Superintendent, Water Works, Ottumwa, Ia.*)

The source of supply in Ottumwa, Iowa, is the Des Moines River which originates in southern Minnesota flowing across Iowa and joining the Mississippi River at Keokuk. The drainage area above Ottumwa is 14,430 square miles, the majority of which is highly cultivated farm land. Many cities and towns are situated along the river above Ottumwa, most of them dumping their raw sewage directly into the river, without any attempt at purification. The city of Des Moines with a population of over 150,000 is the largest, and is located between 90 and 100 miles above Ottumwa by river distance.

The raw water fluctuates widely and quickly in turbidity and bacterial counts, and during the summer months large quantities of algae are present, the raw water, at that time, having a decidedly strong and disagreeable odor. The bacterial count ranges from a few thousand to several hundred thousand per cubic centimeter within a few hours. A maximum count of over 6,000,000,000 per cubic centimeter was reached on one occassion at a time of very low river flow, a heavy coating of ice with snow to considerable depth over the ice, giving in effect a refrigerated pipe line from Des Moines to Ottumwa. (See figure 1.)

The dissolved oxygen in the raw water ranges from 3 to between 12 and 13 p.p.m., rarely falling below the lower figure and holding around 10 to 12 during most of the time when the water is cool.

Free or excess carbon dioxide is usually present in the raw water and ranges from 0 to 15 p.p.m., the minimum, or entire absence, being reached during the summer months when algae are at their greatest intensity. The highest found to date, of 14.96, was reached on February 20th, 1933 when the river was at an extremely low flow and frozen over. On this date the dissolved oxygen was 4.2 p.p.m. and the bacterial count at 37 degrees was 720 and at 20 degrees 2,960 per cubic centimeter.

The total hardness of the raw water on December 21–22–23, 1932 reached 415 p.p.m. of which 102 p.p.m. was non-carbonate, which is the highest recorded since our laboratory was installed. Records of hardness started in February 1932.

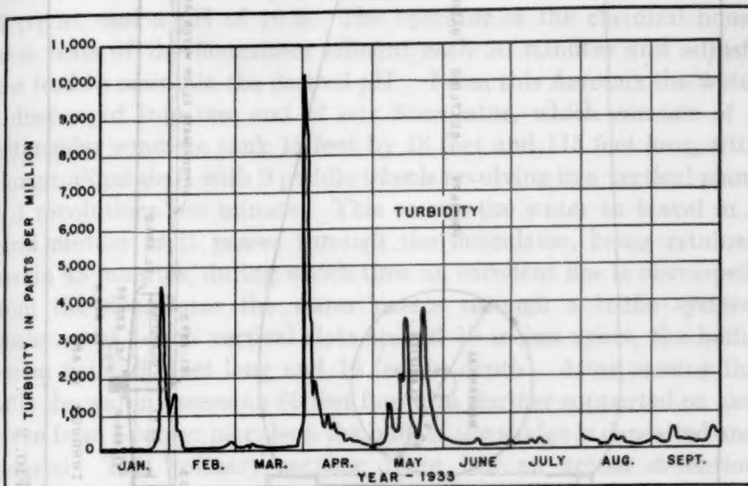

FIG. 1

THE NEW FILTRATION PLANT

After considering all phases of the raw water problem we decided to install the plant which we built in 1932 and placed in operation in February 1933.

The plant consists essentially of the intake, raw water pumps, chemical house, with primary Aeromix, chemical feed machines, and chemical storage; the flocculator, primary settling basin, secondary settling basin, re-carbonation equipment, re-carbonation settling and receiving basins, 8,000,000 gallon per day filtration plant, low lift clear water pumps to final aeration and activated carbon treatment plant, final filtration, and an 8,000,000 gallon clear water storage basin. The layout is shown in figure 2.

In the first step of our treatment the raw water is put through a 20-inch Aeromix, located in the chemical house, which also acts as a quick mix for the lime which we add to the water just below the head of the Aeromix, using crushed quick lime fed through a dry feed machine into a continuous slaking machine in which a temperature of

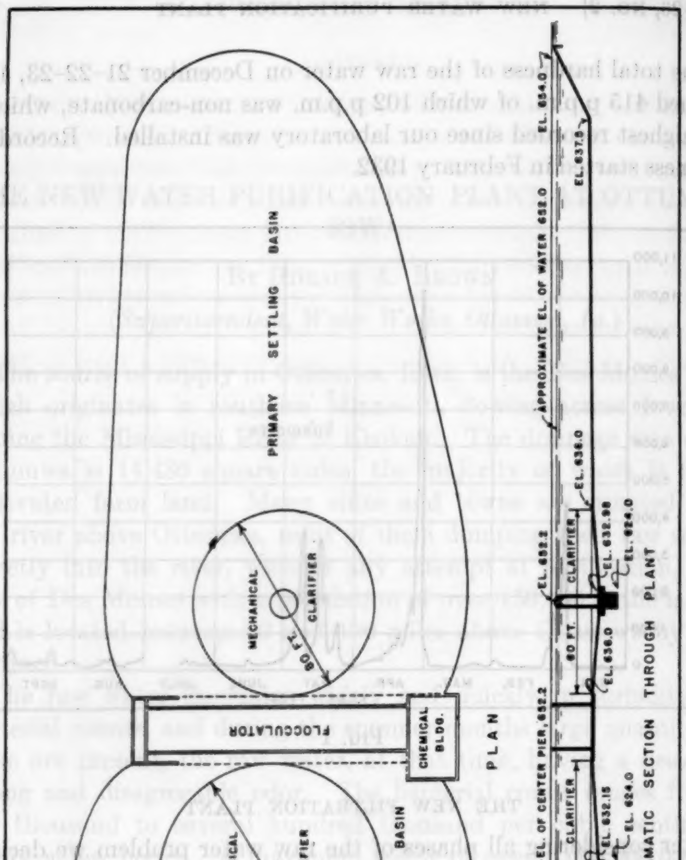
FILTER BUILDING
CLEAR WELL
PIPE GALLERY
FILTER
FILTER
BUILDING
FILTER
FILTER
RE-CARBON-ATION CHAMBER
RE-CARBON-ATION CHAMBER
SECONDARY SETTLING BASIN
MECHANICAL CLARIFIER
100 FT.
FLOCCULATOR
CHEMICAL BLDG.
PLAN
MECHANICAL CLARIFIER
80 FT.
PRIMARY SETTLING BASIN
EL. 654.0
EL. 644.0
EL. 624.0
EL. 654.0
EL. 636.0
100 FT.
CLARIFIER
EL. 632.15
EL. 624.0
EL. OF CENTER PIER, 632.2
EL. 636.0
80 FT.
CLARIFIER
EL. 632.98
EL. 624.0
EL. 632.2
EL. 636.0
APPROXIMATE EL. OF WATER 632.0
EL. 654.0
DIAGRAMATIC SECTION THROUGH PLANT

FIG. 2

180 to 200 degrees Fahrenheit is maintained by the addition of hot water. Lime only is added at this point and in sufficient amounts to maintain a pH of 10.7 at the end of the flocculator. This throws down all the magnesia and converts all bi-carbonates into normal carbonates and leaves a hydroxide at effluent of basin of about 20 to 30 p.p.m. and a pH of 10.5. The operator of the chemical house takes tests of the flocculator effluent each 30 minutes and adjusts lime feed to maintain the desired pH. From this Aeromix the water is discharged into one end of our flocculator, which consists of a rectangular concrete tank 18 feet by 18 feet and 115 feet long, with a longitudinal shaft with 9 paddle wheels revolving in a vertical plane at 3 revolutions per minute. This causes the water to travel in a spiral motion as it passes through the flocculator, being retained therein 45 minutes, during which time an excellent floc is developed. From the flocculator the water passes through a baffle system, consisting of 1-inch vertical slots spaced 10 inches apart, the baffle system being 90 feet long and 16 feet in depth. After passing the baffle the water crosses an 80 feet four arm clarifier supported on and driven from a center pier; here the bulk of the sludge is deposited and removed. This primary settling basin has an actual detention period of 6 hours. The primary Aeromix is so connected that the raw water after aeration, and with or without chemical treatment, can be discharged immediately behind this baffle system and into the primary basin without passing through the flocculator, the thought being that in periods of extreme turbidity, preliminary sedimentation could be used prior to chemical treatment. To date no experiments with this method have been made.

The outlet from this primary settling basin is through four 18-inch tiles placed 4 feet below the surface and equidistant around the outlet end of the basin; these tiles connect to a 30-inch vitrified clay flow line leading back to the chemical house where the water is then treated with soda ash. The amount of soda ash is adjusted to reduce the non-carbonate hardness to a final of 10 to 15 p.p.m. Enough sulphate of alumina is added to bring the pH to 9.8, then it is passed through an "around the end" baffle mixing chamber located under the chemical house. This has a mixing capacity of 20 minutes, then through a baffle system similar to the one just described and into the secondary basin. Connections have been provided so that the effluent from the primary settling basin, in case it is used for preliminary, sedimentation, can be treated with lime, soda ash and sulphate

of alumina, and passed directly into the flocculator, thence through the baffle system into the secondary basin. The secondary basin is equipped with an 100-foot two arm clarifier mounted on and driven from a center pier. The sludge from this clarifier can be discharged into the river as is the sludge from the primary basin, or handled by a return sludge pump and discharged either into the primary Aeromix thence to primary basin or into the around the end baffle mixing chamber and back to the secondary basin, which at the present time is the method of operation.

The secondary basin has a detention period of 4 hours. The effluent from this basin passes through a collecting baffle system which has vertical slots 2 feet in height and ½-inch in width. The top of the baffle is 6 inches under water when operating normally. From behind these baffles the water is led to a suction well located outside the basin and adjacent to the filter house. In the filter house is located a low lift centrifugal pump, which lifts the water into another 20-inch Aeromix through which carbon dioxide gas is sucked into and thoroughly contacted with the water, being discharged into a receiving well outside the filter building and adjacent to the suction well. From this receiving well the water flows into two small receiving basins which are quadrants of circles, one on each side of the filter building, and connected to each other by a 3 by 9 foot passage way around the end of the filter building.

From these basins the water is admitted directly to the filter units through 18-inch hydraulicly operated influent valves located at the back of the filters.

The CO_2 generating equipment consists of an electrically operated mechanical underfeed stoker burning anthracite rice coal. The boiler has attached to it a condenser for absorption of the heat during the summer months. In the winter months the heat is used for heating the building. From the stack of the boiler all of the flue gas is passed into the bottom of a wet and dry scrubber, being sucked through by the pull of the Aeromix on the outlet end and the forced draft of the stoker under the boiler. A flow meter is installed in the gas inlet to the Aeromix and a CO_2 percentage indicator and recorder takes samples at regular and frequent intervals from the flue leading to the scrubber and makes a record of the analysis on the same chart that records the volume of flow.

We have found that the volume of flow is very constant, the water pumpage through the Aeromix being maintained at the uniform rate

of 5,600 g.p.m. The dosage of CO_2 is regulated by changing the percentage by manual adjustment of the air control and the coal feed of the stoker; this enables us to operate on the absolute minimum of coal required to generate the needed CO_2 gas. It requires approximately 400 pounds of coal per million gallons of water treated. The filter operator checks the incoming water every 30 minutes and adjusts the CO_2 percentage when necessary. Usually two or three adjustments per day is all that is needed. You will note the elimination of the usual noisy and troublesome blower. We maintain a residual of about 0.88 to 1.00 p.p.m. of free CO_2 gas in the influent to the primary filters and a pH of 7.7. and no complaints have been received of red water troubles in the distribution system. Our chemist living near the outer limits of the distribution system carefully watches the water at his home in both the hot and cold water lines and all of our employees have been instructed to be on the watch at their residences for any evidence of trouble of any kind. To date no traces have been observed either of red water or deposit of carbonates.

We consider it better practice to sacrifice about one grain of hardness, lost in reducing the pH prior to filtration to about 7.7, than to put a large quantity of normal carbonates onto the filters, resulting in serious cementing of the sand and gravel beds and cracking of the same, with the final result that the filter beds will have to be relaid at quite frequent intervals.

Carrying a pH of 7.7 in the influent to the filters eliminates all this and results in a much better tasting water, and a water which shows no signs, to date, of being aggressively corrosive.

The filter beds are two million gallon units divided by a central wash water gutter into two 1 million gallon filter beds, which operate at the rate of 2 gallons per square foot per minute. The sand used in the filter beds was obtained from Muscatine, Iowa and has an effective size of 0.38 to 0.45 millimeters and uniformity coefficient of 1.3 to 1.5. It is 30 inches in depth, resting upon a gravel bed graded from $\frac{1}{32}$ to $1\frac{3}{4}$ inches and 18 inches in depth above the false bottom, the valleys of which are filled with the coarse gravel carefully hand placed and avoiding the use of flat or elongated stones.

The filter bottom used in the new filters consists of a false bottom made of pre-cast concrete blocks finished with inverted "V" shaped tops, these blocks being 6 inches wide at the base and spaced $\frac{1}{2}$-inch apart, and supported 18 inches above the real bottom by two concrete

walls 8 inches thick running longitudinally through the filter tank, separating the compartment under the false bottom into three separate chambers. Openings 6 by 6 inches are provided on 2 feet centers through these supporting walls in order that the pressures in the chambers under the false bottom may be equalized (see figures 3 and 4). Wash water is supplied to, and the effluent taken from, these compartments through 8-inch cast iron pipes running the full length of these compartments drilled with two rows of 1-inch holes 8-inches apart. These rows of holes are located in the bottom third of the 8-inch pipe so that the force of the jet is directed downward away from the false bottom and against the real floor. This filter

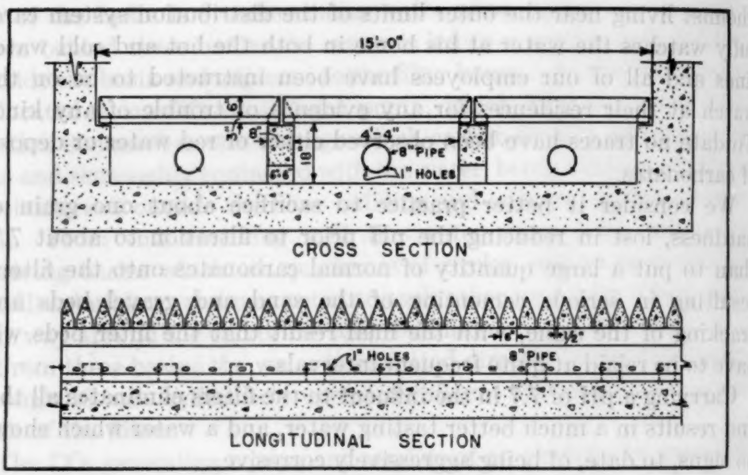

FIG. 3. FILTER BOTTOM

bottom seems to provide an excellent distribution of wash water and eliminates all unwashed area in the bottom of the filter. The false bottom blocks are held in position at their ends by cement mortar placed by the use of a small trowel and finished to the same slope as the main blocks resulting in an inverted "V" ridge immediately above the supporting wall below and at right angles to the pre-cast blocks.

The water used in washing filters is stored up in a basin under two of the units and returned to the primary basin through a split suction on the raw water pumps which take their suction from a suction well under one corner of the filter building. Under the remainder of the

filter building is a small clear water storage basin from which low lift centrifugal pumps take the water and deliver it to the final Aeromix where final aeration takes place and activated carbon in the amount of 25 to 30 pounds per million gallons is introduced into the clear water. The water then passes into a settling basin with 2 hours detention, then through the old rapid mechanical filters at a rate of 3

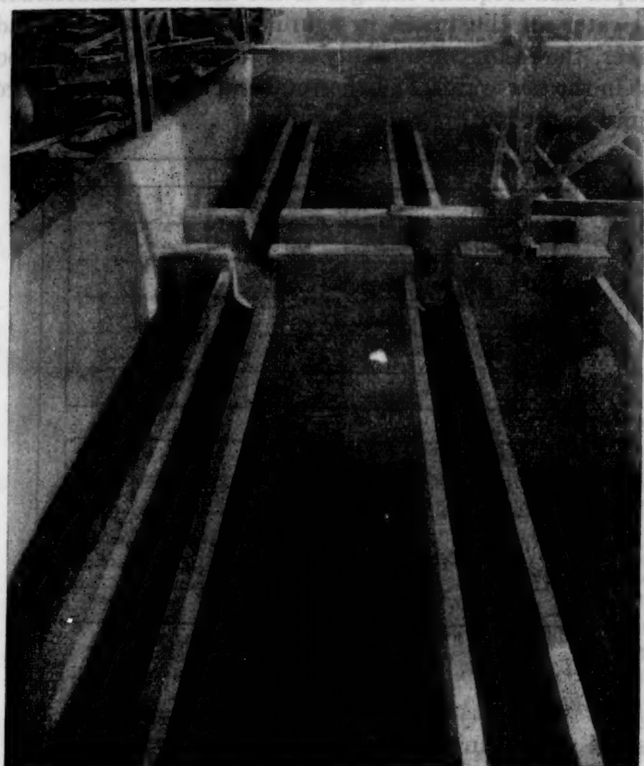

FIG. 4

gallons per square foot per minute which removes all of the carbon giving a fine tasting water, sprakling clear and free from all odors. The dissolved oxygen in the final water averages about 7 p.p.m. during warm weather and gradually increases as the water gets cooler until around 12 p.p.m. is reached in real cold weather. From these filters the effluent connects to a 42-inch cast iron flow line, 800

feet in length, which leads to a small pump well and to an open concrete lined clear water reservoir with a capacity of 8,000,000 gallons.

The water is given a final treatment with ammonia and chlorine in the suction line of the high service pumps which deliver the water to the consumer.

OPERATING RESULTS

The rapid and frequent changes in the mineral characteristics of the raw water are illustrated in figure 5, showing the rise and fall of the river, the results of the daily tests for total and non-carbonate hardness in the raw water, and the total and non-carbonate hardness in the finished product.

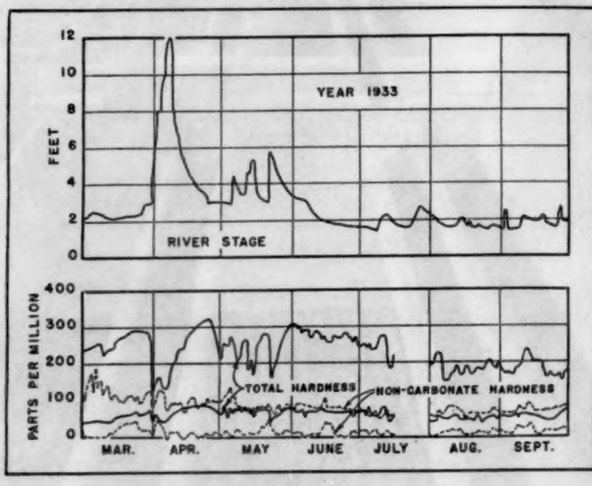

FIG. 5

COST DATA

A résumé of the unit cost of this operation will probably be of interest. The total amount of water treated each month from March to September, inclusive, the total cost of treatment per million gallons, the hardness of the raw water, carbonate and non-carbonate, the hardness of the finished product, carbonate and non-carbonate, the reduction in hardness, carbonate and non-carbonate, and the cost of the reduction in hardness for each part per million, per million gallons of water treated for carbonate and non-carbonate hardness are shown in table 1. You will note that the softer the raw water the greater the cost per part per million to reduce the

hardness and the higher the hardness in the raw water the lower the cost per part per million to reduce it, indicating that the last few remaining parts per million of hardness are the most expensive to remove.

We made our own design of this purification system. The design was detailed and the working drawings were prepared by Consoer, Older & Quinlan of Chicago, to whom we feel very grateful for suggestions and ideas brought out during their part of the work. We are indebted also to Mr. Lowe of the "Proportioneers" for his assistance in working out some of the details of the re-carbonation layout.

TABLE 1

Chemical cost data

1933 MONTH	MILLION GALLONS TREATED	COST PER MILLION GALLONS IN DOLLARS	HARDNESS, P.P.M.				P.P.M. REDUCTION		COST PER MILLION GALLONS PER P.P.M. IN CENTS	
			Raw		Final					
			Carbonate	Noncarbonate	Carbonate	Noncarbonate	Carbonate	Noncarbonate	Carbonate	Noncarbonate
March	73.106	17.48	201.3	52.7	83.4	16.0	117.9	36.7	8.3	21.1
April	96.853	17.62	170.1	65.5	81.3	7.1	88.8	58.4	8.9	17.0
May	117.266	17.58	169.8	66.0	69.9	9.3	99.9	60.6	8.5	15.0
June	96.700	22.11	205.0	65.4	68.4	5.4	136.6	60.0	7.5	19.8
July	83.810	20.46	172.8	55.5	54.0	1.0	118.8	54.5	7.8	20.5
August	72.537	18.62	136.1	45.5	57.1	0.8	79.0	44.7	11.7	21.1
Sept.	65.813	15.68	129.1	46.0	57.3	9.5	71.8	36.5	11.5	20.2

	dollars per ton FOB. Ottumua, Iowa
Sulphate Alumina	26.40
Line	9.00
Soda Ash	28.80

Construction was carried out under a contract with Meier Bros. of Ottumwa, on the basis of actual cost plus a fixed sum to cover use of equipment and working capital. The actual direction of the work and the method of prosecuting the work was planned by the Superintendent of the Water Works. All labor was taken from the unemployed registration list and so rotated that over 1,400 different men were employed during the construction.

The total cost of the 8 m.g.d. purification plant with chemical house, flocculator, settling basins and all equipment was $227,832.00. The cost of the 8,000,000 gallon clear water storage basin was $33,296,

and the 42-inch cast iron flow line laid beneath the power canal cost $47,397.00. The improvement was financed by the issuance of Water Revenue Certificates payable only from the operating revenue of the Water Department. No taxes have been levied for water works purposes since 1926.

(Presented before the Missouri Valley Section meeting, October 27, 1933.)

AN IMPROVED METHOD FOR MEASURING POROSITY OF SAND

By Roberts Hulbert and Douglas Feben

(*Senior Chemists, Department of Water Supply, Detroit, Mich.*)

In a previous paper[1] the writers developed an empirical formula from experimental data for calculating the loss-of-head resulting from the passage of clear water through clean, graded filter sand. It was first derived from measurements made with very uniform, round-grain sands and then applied to graded filter sands of varying grain shapes. The applicability of the formula to a non-uniform, graded sand was made possible by calculating separately the loss-of-head for each uniform fraction retained between screens, as disclosed by sieve analysis, and assuming that the percent of sand by weight is identical with the percent of each size by depth when placed in a filter. The total loss-of-head for the full depth is then obtained by summation.

The discrepancies found between the calculated and measured losses in these graded sands was accounted for by the difference in grain shape and consequent variable porosities. The term porosity was therefore introduced into the formula in order to reduce these errors to a point compatible with practical usefulness. In order to use the final formula it is necessary that the porosity of any given sand be experimentally determined under conditions of hydraulic grading, such as prevail in the rapid sand filter bed after backwashing.

The procedure originally devised and recommended for the determination of porosity was as follows:

"The Jackson Turbidimeter outfit, found in nearly all water laboratories provides a glass tube of approximately 2.8 cm. diameter by 75 cm. long, and volumetrically graduated. This tube is firmly clamped in a vertical position and half filled with water to give a column of about 40 cm. height. A wide-stem funnel is now secured above the mouth of the tube, but not in contact with it. A representative, 400 gram sample of the sand is accurately weighed,

[1] "Hydraulics of Rapid Filter Sand," Hulbert and Feben. Journal, 25; 1, January, 1933.

and poured in about ten successive fractions through the funnel into the tube, allowing each pour (of about 40 gms.) to settle before the next is introduced. In the process of falling through the water column, each portion of sand will tend to grade itself hydraulically into ten, minature, stratified, sand layers. Throughout the pouring operation, extreme care should be exercised not to touch or jar the apparatus in any way to cause a false settlement of the sand column. A reading of the total volume of the sand in the tube is then made, and knowing its weight, the porosity can be calculated in terms of void percentage. Given the constant 2.65 as the specific gravity of silica sand, its porosity can be calculated by the equation:

$$\text{porosity} = \text{percent void} = 100 - \frac{37.7\, w}{v}$$

where w = weight of sand in grams, and v = volume of sand in cubic centimeters as graded in the tube.

There are several sources of error which are inherent in the above method, hence it is to be regretted that the improvements given hereafter were not worked out prior to the publication of the original work. A brief enumeration of the difficulties and sources of error in the original method may be given. In the first place, the successive pouring of the several aliquot portions of the sample into the tube, while it gives satisfactory grading of each individual pour, fails to produce a continuous grading of the whole sand column, which is desirable in order to more nearly duplicate the effect of actual backwashing of the sand in a filter unit. Several check determinations of porosity should be run on a given sand and the results averaged, which in case of the original method, necessitates weighing out several samples of the sand and emptying the tube and repeating the pouring operations for each check. In pouring the sand portions the least disturbance of the tube or bench on which it is mounted will cause further subsidence of the settled sand column. During the process of pouring if sand be inadvertently deflected against the side of the tube the same effect has been noticed. False settlement of the sand in these ways introduces appreciable error. Furthermore the sand is apt to carry air adhering to individual grains, which changes the relative weight of the particles and interferes with the process of true grading to size, such as takes place in a filter unit.

The revised method, modified in such a way as to yield more accurate and reliable results is as follows:

Pour approximately 150 grams of representative sand sample into the Jackson Tube, which is half full of water. The contents are well shaken up to remove any air entrained with the sand. If the water now appears dirty it is

decanted from the sand, taking precaution against any loss of the latter. Decantation is continued until the sand is clean and free from air, and the tube is then completely filled with water and stoppered. It is then mounted in a clamp assembly on a laboratory support stand in such a way that it can be rotated about an axis at right angles to the tube length. A rubber pad should be placed under the bottom of the tube, which is now clamped firmly just above the middle. The tube is rotated one half turn (180 degrees) taking care to hold the cork from dropping out, and the entire sand sample is allowed to settle to the cork. The tube is then quickly inverted, right side up with the bottom resting upon the rubber pad, the clamp being loosened meanwhile if necessary. These manipulations should be accomplished before the first grains of sand have settled down upon the bottom of the tube, and settlement of the entire column of sand is allowed to take placed with the operator standing clear of the apparatus. When this process is complete the volume should be read immediately, after which the calculation of porosity may be made as before.

By this method very complete size-grading of the sand is obtained; it is kept clean and air-free; and moreover, the determination may be repeated as may times as desired on the same sample without removing it from the tube. Using this revised method, very carefully checked porosity determinations on the sixteen graded sands used in the original work, give the following results:

Sand number	*Porosity (percent void)*
9	43.01
10	41.11
11	46.87
12	45.54
13	42.08
14	42.66
15	46.33
16	43.65
17	42.09
18	43.02
19	41.79
20	54.16
21	41.49
23	49.01
24	51.60
25	48.10

The use of these more accurate measurements changes two of the constants in the original formula, which now reads as follows:

$$l = \frac{27}{10^5}\left[\frac{d \cdot r(73 - p)}{g^{1.80}(t + 20.6)}\right]$$

where l = loss of head in feet
d = sand depth in inches
r = rate of flow in m.g.a.d.
p = porosity (percent void determined by method here given)
s = sand size in millimeters (50 percent median sieve size)
t = temperature in degrees F.

For the complete derivation of the formula and the method of its application the reader is referred to the authors original article.

FRESH-WATER MUSSELS AND THE BACTERIAL CONTENT OF WATER[1]

By M. P. Moon and Mary Alice Hamilton

(Department of Medical Bacteriology and Preventive Medicine, University of Missouri School of Medicine, Columbia, Mo.)

In the preliminary paper of a series of experiments conducted to determine the bactericidal power of fresh-water mussels, the conclusion was drawn that the mussels cannot be regarded as an important factor in the general destruction of bacteria.

It was suggested that the mussels might exert a selective bactericidal effect on certain bacteria, particularly organisms of the colon-typhoid group. This effect was indicated in table 3 of the first paper in which there was a decrease in the bacterial content in the 24 hour count when B. typhosus and B. coli were subjected to the action of the mussels.

TAP WATER

This paper will deal with the effect of the mussels on the known B. coli content of various samples of water. B. coli was used as the typical example of the intestinal group of bacteria, which is found most abundantly in sewage polluted streams. As in paper No. 1, the mussels that had been subjected to running tap water for several weeks were scrubbed and again subjected to running tap water for 3 or 4 days. The shells were paraffined so that external contamination was eliminated as much as possible. One mussel was placed in each sterile battery jar containing 4 liters of tap water and incubated in a bath of running tap water, which had a relatively constant temperature of 19° to 22°C. Tap water was used in the battery jars instead of distilled water because of its similarity to water in streams. There is no possibility of quantitative contamination by the tap water, as the highest initial plate count of the tap water was not over 10 colonies per cubic centimeter, and

[1] This work was done in conjunction with the U. S. Bureau of Fisheries Research Laboratories, Columbia, Missouri.

after 4 days' incubation, the average count was less than 100 colonies per cubic centimeter.

The tap water was inoculated with 0.5 cc. of a 24 hour bouillon culture of B. coli. Table 1 shows that in tap water alone there was a gradual increase in the number of B. coli.

Table 2 shows that the fresh-water mussels alone add a large number of bacteria to the water. B. coli was not found in any of the uninoculated mussels.

TABLE 1

Increase of bacteria in inoculated tap water

Results expressed in bacterial colonies per cubic centimeter

SAMPLE NUMBER	INITIAL COUNT	24 HOURS	48 HOURS	72 HOURS
1	6,800	36,000	55,000	11,000
2	5,760	64,000	1,200,000	
3	3,100	61,000	71,000	88,320,000
Average....	5,220	53,665	975,330	44,160,000

TABLE 2

Increase in the bacterial content of tap water due to the presence of fresh-water mussels

Results expressed in bacterial colonies per cubic centimeter

SAMPLE NUMBER	24 HOURS	48 HOURS	72 HOURS
4	2,400	17,200	3,000
5	2,100	11,900	2,000
6	32,200	109,400	
7	30,500	116,500	
8	2,000	6,000	62,720,000
9	1,800	9,000	60,160,000
Average..........	11,830	45,000	30,721,250

The tap water was inoculated with 0.25 cc. of 24 hour bouillon culture of B. coli.

In comparing tables 1, 2, and 3, the B. coli content increases more rapidly in the control than in the jar containing the fresh-water mussel. The period from the initial count to the 48 hour count was used. The 72 hour count included more factors than the effect of the fresh-water mussels. If the mussels exert any practical bac-

tericidal effect, the evidence should be demonstrated in 24 or 48 hours under the plan of the experiments.

Table 3 shows that in general there is a gradual increase in the B. coli content of the water. In individual samples, however, the lower the initial inoculation, the more evidence of the lack of bactericidal power; where the initial inoculation is high, a decrease is noted in 24 hours.

TABLE 3

Effect of fresh-water mussels on the bacterial content of inoculated tap water

Results expressed in bacterial colonies per cubic centimeter

SAMPLE NUMBER	INITIAL COUNT	24 HOURS	48 HOURS	72 HOURS
10	7,000	4,000	4,000	1,000
11	5,000	2,100	10,000	1,000
12	6,400	2,100	4,000	1,000
13	5,000	3,000	6,000	1,000
14	11,710	55,360	980,000	
15	13,750	54,160	110,000	
16	13,365	49,360	100,000	
17	12,545	54,400	99,800	
18	7,900	50,000	65,000	96,000,000
19	6,590	45,000	87,500	76,800,000
20	7,500	60,000	95,000	1,200,000,000
21	6,000	62,500	87,500	1,250,000,000
Average.....	8,472	38,280	136,550	326,600,000

TABLE 4

Comparison of average results from tables 1, 2, and 3

Results expressed in bacterial colonies per cubic centimeter

CONTENTS OF SAMPLE	INITIAL COUNT	24 HOURS	48 HOURS	72 HOURS
Water + bacteria............	5,220	53,665	975,330	44,160,000
Water + bacteria + mussel....	8,472	38,280	136,550	326,600,500
Water + mussel................		11,830	45,000	30,721,250

Apparently fresh-water mussels exert little or no bactericidal action on the B. coli content of water.

STREAM WATER

For more practical knowledge of the effect of fresh-water mussels on the bacterial content of water, a series of experiments was con-

ducted in which stream water was used instead of tap water. Samples of water from the Mississippi River (foot of Arsenal Street, St. Louis, Mo.) and from the Missouri River (Booneville, Mo.) were secured. The total bacterial count was obtained on plain agar plates and the B. coli content was obtained from lactose fermentation tubes. A series of dilutions was made in the lactose

TABLE 5

Effect of fresh-water mussels on bacterial content of the high initial inoculation of tap water

Results expressed in bacterial colonies per cubic centimeter

SAMPLE NUMBER	INITIAL COUNT	24 HOURS	48 HOURS	72 HOURS
22	819,000	100,000	120,000	20,000
23	1,203,200	70,000	68,000	21,000
24	1,344,000	80,000	105,000	20,000
25	1,171,200	80,000	114,000	45,000
Average.....	1,134,100	82,500	101,750	26,500

TABLE 6

Effect of fresh-water mussels on the total bacterial count of the Mississippi River water

Results expressed in bacterial colonies per cubic centimeter

SAMPLE NUMBER	INITIAL COUNT	24 HOURS	48 HOURS	72 HOURS
1	9,700	244,000	210,000	49,000
2	9,700	339,000	410,000	132,000
3	9,700	33,000	50,000	9,000
4	9,700	91,000	30,000	64,000
Average....	9,700	176,750	175,750	63,500
Control: Missisippi River water				
5	9,700	70,250	10,000	13,000

fermentation tubes, and Endo plates were made from the highest dilution showing gas. The B. coli count obtained from the presumptive test is to be considered only as an index and not an accurate count.

According to tables 6 and 8, there is no evidence of a general bactericidal power of fresh-water mussels; in fact, the evidence

apparently is that the fresh-water mussels add to the total bacterial content, which fact is also indicated in table 2.

In tables 7 and 9, there is no evidence of a selective bactericidal action of river water. In the water in which the fresh-water mussels were present, the B. coli content increased, but not as rapidly as in the controls (water without the fresh-water mussels), showing that the multiplication of the B. coli was slightly inhibited.

TABLE 7

Effect of fresh-water mussels on the B. coli content of the Mississippi River water

Results expressed in bacterial colonies per cubic centimeter

SAMPLE NUMBER	INITIAL COUNT	24 HOURS	48 HOURS	72 HOURS
1	1,000	1,000	1,000	1,000
2	1,000	1,000	2,000	1,000
3	1,000	1,000	500	100
4	1,000	1,000	500	500
Control: Mississippi River water				
5	1,000	10,000	5,000	100

TABLE 8

Effect of fresh-water mussels on the total bacterial count of the Missouri River water

Results expressed in bacterial colonies per cubic centimeter

SAMPLE NUMBER	INITIAL COUNT	24 HOURS	48 HOURS
1	3,450	34,000	22,000
2	3,450	14,000	13,000
3	3,450	12,000	23,000
4	3,450	7,800	19,000
5	3,450	15,300	22,000
Average..........	3,450	16,650	19,800
Control: Missouri River water			
6	3,450	8,000	5,000

ADDITION TO WATER BY MUSSELS

A number of experiments were conducted to determine the possibility of the mussels adding any nutritive material to the water.

Ten cubic centimeter samples of water in which the mussels had been placed for 72 hours were autoclaved. Controls consisted of autoclaved tap water. A loopful of a 24 hour bouillon culture of B. coli was added to each tube.

TABLE 9

Effect of fresh-water mussels on the B. coli content of the Missouri River water

Results expressed as B. coli colonies per cubic centimeter

SAMPLE NUMBER	INITIAL COUNT	24 HOURS	48 HOURS
1	100	50	200
2	100	200	−100
3	100	200	−100
4	100	500	200
5	100	400	50
Average..........	100	270	130
Control: Missouri River water			
6	100	400	500+

TABLE 10

Experiment to determine if any nutritive value has been added to the water by fresh-water mussels

Results expressed in bacterial colonies per cubic centimeter

SAMPLE NUMBER	TUBE CONTENT	INITIAL COUNT	24 HOURS	48 HOURS
A	Tap water	720	600	0
B	Tap water	1,560	320	3
Average......................		1,140	460	2
C	Mussel water	1,500	91	1
D	Mussel water	1,450	120	3
Average......................		1,475	105	2

Table 10 shows that the bacteria decrease more rapidly in the mussel water than in the tap water, which may be indicative of some bactericidal effect of the mussels.

Destruction of any nutritive material secreted by the mussels in tap water might be due to autoclaving. Another set of experiments was conducted, using mussel water filtered through a Berkefeld

filter. Water in which the mussels had been placed for 24 hours (Series I), 48 hours (Series II) and 72 hours (Series III) was filtered through a Berkefeld filter and collected in 40 cc. quantities (designated mussel water). Controls consisted of 40 cc. of autoclaved tap water. One-tenth cubic centimeter of a 24 hour bouillon culture of B. coli was added to each of the above tubes. Results are expressed in table 11.

TABLE 11

Experiment to determine if any nutritive value has been added to the water by fresh-water mussels

Results are expressed in bacterial colonies per cubic centimeter

SAMPLE CONTENT	INITIAL COUNT	24 HOURS	48 HOURS	72 HOURS
Tap water	947,000	4,320,000	3,640,000	3,480,000
	20,000	4,300,000	8,000,000	3,970,000
	1,670,000	13,500,000	20,900,000	11,700,000
Average	879,000	7,366,000	10,846,700	6,376,700
Mussel water, Series I	1,011,200	14,200,000	4,800,000	1,840,000
Series I	985,600	6,420,000	200,000	160,000
Average	998,400	10,310,000	2,500,000	1,000,000
Mussel water, Series II	1,380,000	45,000,000		430,000
Series II	1,320,000	8,500,000		80,000
Average	1,350,000	26,750,000		255,000
Mussel water, Series III	660,000			
Series III	1,120,000	2,500,000	100,000	10,000
Average	890,000	2,500,000	100,000	10,000

Table 11 shows that in tap water alone there was a gradual increase in the number of B. coli. This fact is also observed in table 1, and is constant in these experiments. No decrease in the B. coli content of the inoculated mussel water was found until after the 48 hour interval. A slight bactericidal effect is thereafter noticed when comparison is made with the B. coli content of the inoculated tap water. There is no evidence that the mussel added any nutritive material to the water.

SUMMARY

These experiments suggest that fresh-water mussels in contaminated water exert little, if any, or at least no practical bactericidal action. There was no evidence of a general bactericidal effect or of a selective bactericidal effect.

These experiments apparently show that fresh-water mussels are not of any great value in the destruction of bacteria in general, nor are they important in the destruction of the most important group of bacteria with which streams may be contaminated,—the colon-typhoid group.

The fact that oysters and shell-fish when removed from polluted waters to waters free from pollution, in which after a few days organisms of the colon type are practically eliminated, may be due to the effect of continued dilution by means of which the bacteria are carried away, and not due to any action of the oysters or shell-fish themselves.

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3. Park and Williams. Pathogenic Microorganisms, 8th Edition.

SOCIETY AFFAIRS

THE INDIANA SECTION

The 26th annual meeting of the Indiana Section was held at the Anthony Hotel, Ft. Wayne, Ind., on December 6 and 7, 1933. The meeting was deferred from last spring on account of the bank situation existing at that time. The present dates were chosen to follow immediately the dedication ceremonies at the new water purification and softening plant just now going into operation. The raw water is impounded on the St. Joseph river and brought to the treatment plant, which is located at the junction of the St. Joseph with the St. Mary. The plant includes facilities for aeration, chemical treatment followed by mixing and coagulation, sedimentation and filtration through rapid sand filters. Formerly the city has been supplied with very hard ground water high in iron. The water purification plant is built of Bedford stone and both the exterior and interior are very attractive.

The meeting of the section opened with about 100 present, the total registration being 175. The first morning was devoted to round table discussion on "Collections and Meters." Mr. H. A. Dill led the discussion and reported the information obtained from questionnaires sent to a number of Indiana cities. The importance to public health in general of supplying pure water to the entire population has made it necessary to revise the former rules in connection with collection of bills. In practically all cases, the regular rules in regard to shut-off for non-payment have been modified. Most departments are accepting partial payment of accounts with no charge for turning on if the water has been shut off. The percentage of delinquencies was found to run from 2.5 to as high as 50 per cent. In most cases, some payment is made by relief organizations or township trustees. In about half the cases it was found that some of the customers were allowed to work out their bills. Also in about half the cases the landlords are held responsible for the non-payment. The water departments are not allowing their desire to make a good financial showing overshadow the humanitarian element in this period of depression. Mr. F. C. Jordan called attention to the fact that

while revenues and customers have been very much reduced the office work has been increased about 50 percent on account of the unusual situation. He reported that his company has established what is known as the "Sympathetic Department" where customers unable to pay present their situation and where the best arrangement possible is made. Mr. C. C. Foutz of LaPorte reported that abstractors are coöperating to the extent that clear title is not shown as long as water bills are unpaid. This in effect puts the responsibility on landlords in cases of rental property. In LaPorte collections through 1932 were not affected by the economic situation, but since that time about 20 percent of domestic places are delinquent. These accounts are being carried. Since the plant is municipally owned, if the delinquent bills were paid by the township trustee it would be only a matter of trading money. In some cases certain relief organizations have paid the meter deposit but none of the subsequent bills.

In discussing the subject of meters, Mr. F. C. Jordan stated that while it was generally accepted that only 70 to 80 percent of the water pumped is accounted for, they have raised this to 88.2 percent with the expectation that it may be brought to as much as 91 percent before the cost of the improvement will be greater than the saving in water. This high percentage is realized through the coöperation of meter readers who by ear have located more than 500 leaks on service lines. The 4-inch and 6-inch meters have been replaced with two or three 2-inch meters to avoid slippage at very low flows. Fire lines are not metered but are inspected regularly and at this time no evidence is found of theft of water from them. About 2 percent is chargeable to street and sewer flushing and fire use. Mr. Wm. Luscombe, of Gary, reported that he had accounted for 85 to 88 percent of the water pumped by exercising the greatest vigilance. He agreed with a previous speaker that straight reading meters were less satisfactory than round.

Mr. Chas. Brossman, Consulting Engineer, presented a paper "Water Works Construction with Relief Labor" in which he analyzed the cost and determined that about 41 percent of the cost of a project goes for labor directly, with about 80 percent of the total expenditure being made within the state itself. An examination of the cost of repaying under average conditions, shows that for 17 projects studied, the cost per consumer is only 76 cents per year, with some of them as low as 21 cents per capita per year. In one case the cost goes to $2.35 per capita but the indebtedness will be paid with no increase in

the present rates. In almost all cases considered, the cost per capita for poor relief is double that for repaying the investment. Mr. Brossman urged the superintendents to take advantage of the Civil Works program in repairing the physical plant and extending mains when possible. In the discussion of this paper it was brought out that the CWA will in cases of necessity purchase material, but prefers that their entire expenditure go into payroll with materials supplied by the supervising unit.

Mr. W. C. Hoad in presenting the subject "The Value of Soft Water to a Community" emphasized the intangible value since it is more important than the actual money saving due to reduction in soap and softening chemicals and the maintenance of distribution system and plumbing, although he recognized the very great money importance of soft water to certain industries. While many people are affected by changing from one type of water to another, the metabolistic interference of high calcium waters is considered to be negligible. He insisted that the value of soft water is to be found in increased cleanliness, its good repute and in the comfort and pleasure of its users.

"Better Fire Protection" was discussed by Clarence Goldsmith in which he stressed the importance of maintaining as good maps as can be made showing the pertinent facts in regard to the water distribution system which include the location of hydrants, shut-off valves, responsibility areas and weakness in the system. He urged very frequent inspection of all hydrants and gate valves and stressed the importance of adequate marking of those operating in other than the standard fashion. The distribution system should be under a planned annual repair program so that no part of it will be found to be faulty when needed.

The dinner meeting was addressed by Merle Sidener of Indianapolis and his talk broadcast by WOWO. He took the position of a consumer and represented himself to be open to conviction in the matter of water and its value, but insisted that the water departments have disregarded their customers for the most part and failed to tell them through the medium of advertising of new uses of water and of proper methods for its general use.

The morning of December 7 was given over to a consideration of the Public Works program, the meeting being addressed by L. A. Geupel, Chief Engineer, Indiana State Division of Health and A. M. Davis, Field Representative of the A. W. W. A. Water supply and sewage

disposal projects are on the PWA preferred list. The work carried on in Indiana at this time under the CWA involves 36 water plants and 86 sewage projects. There are 112 projects so far presented to the State Board, 91 of which have been forwarded to national headquarters and 27 approved. Of these, 31 are water works and 18 sewage disposal. The projects approved thus far include six water plants and four sewage projects with an estimated cost of more than three million dollars. The total sum applied for is more than twenty-six million dollars. Mr. Davis has been occupied for several months in assisting city officials by supplying them accurate information on PWA and he stated that on at least 40 of the projects, the A. W. W.A. has been of material help.

Mr. R. L. McNamee gave an illustrated description of the unusual features of the Ft. Wayne water softening plant after which the meeting adjourned to inspect the new works.

The following officers were elected: President, W. C. Mabee, Indianapolis Water Co., Indianapolis, Ind.; Vice-President, C. C. Foutz, Supt. Water Dept., LaPorte, Ind.; Secretary-Treasurer., C. K. Calvert, RR 3 Box 976 H, Indianapolis, Ind.; Assistant Secretary, Bernard H. Jeup, 102 N. Senate, Indianapolis, Ind.

C. K. Calvert,
Secretary-Treasurer.

ABSTRACTS OF WATER WORKS LITERATURE[1]

FRANK HANNAN

Key: American Journal of Public Health 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Legal Duty to Supply Water. LEO T. PARKER. Water Works Eng., 86: 3, 105, February 8, 1933. Unless private water company has guaranteed under written contract adequate service for fire extinction, no liability can attach to it for failure to furnish such service. Where doubt as to purport of contract arises, Court will interpret legal obligations assumed by parties, and, usually, case is decided in accordance with logical construction of contract. It is universally conceded by Courts that either municipality, or private company, may prescribe and enforce regulation providing for shutting off water from consumer in default. In some jurisdictions, municipalities furnishing water to their inhabitants are authorized by state laws to shut off service and to keep it shut off until all arrears have been paid. Under such authority, it has been held that municipality may turn off water notwithstanding fact that since delinquency premises have been occupied by another tenant.—*Lewis V. Carpenter.*

Municipal Water Softening. E. L. LIUM. Water Works Eng., 86: 7, 277, April 5, 1933. Grand Forks, N. D., gets its water from Red Lake River. Average chemical dosage is 17 grains lime, 2 grains soda ash, and 0.65 grain of sodium aluminate per gallon. Hardness is reduced from 278 to 81 p.p.m. Sufficient carbon dioxide is added to bring pH to between 8.3 and 8.6. Cost of softening is $14.25 per m.g. Including retirement of bonds, total cost of softening to consumers is $10,156 per year. Based on estimates advanced by other cities, removal of 197 p.p.m. of hardness should save $20,640 per year in soap. Besides this large saving are enjoyed other benefits of soft water, such as better boiler feed water, freedom from fixture stains, and general personal satisfaction.—*Lewis V. Carpenter.*

Carrying 42-inch Line Over Bridge. HAROLD W. GRISWOLD. Water Works Eng., 86: 7, 281, April 5, 1933. Plans for widening bridge in Hartford, Conn., located piers and abutments directly over existing 42-inch cast iron water line. As break in this line would be disastrous, both to bridge and to water supply, it was decided to carry the pipe over the bridge under the foot walk. To conserve head room, flange-connected steel headers, with three 21-inch outlets, were used. Steel lines and headers were completely installed before closure. Line was taken out of service; pipe which was to be abandoned

and anchorages at either end of bridge were blown out with dynamite. Closure pieces were then measured, cut, and set. Period during which line was out of service was materially shortened by use of dynamite.—*Lewis V. Carpenter.*

Rights of Water Works Employees. LEO T. PARKER. Water Works Eng., 86: 7, 284, April 5, 1933. Municipal water department employee is not entitled to recover salary in arrears, unless he proves that he rendered services to the municipality, and thereby earned the salary. In many instances, state laws require that public officers may not legally be removed from office without legal notification and hearing. Ordinance regulating appointment is valid. Reasonably convincing proof that municipal employee appeared for duty in intoxicated condition justifies his dismissal from service. Laws which limit time within which to file suit for various causes are valid and enforceable with respect to shortage of accounts made by public officials, just as with other debts. Breach of an official bond results when official fails to account for moneys, or otherwise fails to comply with law regarding public money in his possession. An attorney-at-law may not divulge secrets or confidential information imparted to him by a client.—*Lewis V. Carpenter.*

Laying Pipe Over Rough Country. C. LELAND WOOD. Water Works Eng., 86: 8, 319, April 19, 1933. Herkimer, N. Y., got its water supply from shallow wells up to 1928. Supply was then increased by constructing small diversion dam across Mill Creek, 20 miles from city. Impounding reservoir has capacity of 1 million gallons. Main is of cast iron bell and spigot pipe, in 12-foot lengths, about one-half being 16-inch, and remainder, 14-inch. Air-valves are located at all high points. Three gate valves are inserted to facilitate repairs without emptying entire line. A large percentage of pipe line route is very rough and wooded. Storage reservoir at city is 325 feet square. Turbine generator set, using part of incoming water under head of 50 feet, is located at reservoir and furnishes 8 kw. for lighting and general use around buildings. Water is treated with ammonia and chlorine at intake house.—*Lewis V. Carpenter.*

Public and Private Water Supplies in Iowa. JACK J. HINMAN, JR. Water Works Eng., 86: 9, 362, May 3, 1933. From 700 to 800 samples of water are analyzed each month. About 15 percent of private shallow wells and 44 percent of public shallow wells are approved: of private deep wells, 61 percent and of public deep wells, 73 percent are approved. Most common faults are open casings and loose top, allowing surface pollution to enter. State puts up approval signs for cities with good water. Tourists should drink only approved water.—*Lewis V. Carpenter.*

Delphos Loses Pollution Suit. Municipal Sanitation, 4: 4, 136, April, 1933. Verdict of $3,924.33 was recently returned to Mrs. CATHERINE HORSTMAN by the Allen County common pleas court in $25,000 damage suit against the city of Delphos, Ohio, for pollution of Jennings Creek. Mrs. HORSTMAN and plaintiffs in 22 similar suits claimed that their properties had been damaged by sewage emptied into Jennings Creek by city. City counsel con-

tended that manufacturing plants within city, and not city itself, were responsible for polluted conditions.—*R. E. Noble.*

Disease From Polluted Water. LEO T. PARKER. Municipal Sanitation, 4: 5, 164, May, 1933. Municipality generally may be liable in damages for sickness or death resulting from impure water, if testimony proves that polluted water caused illness. In GENTRY *v.* Hovious, 55 S.W. (2d) 753, suit was filed for damages. Plaintiff claimed that she contracted typhoid by drinking polluted city water: evidence showed that water contained colon bacilli. Higher Court refused damages, exonerating water because other members of family were not affected. In JONES *v.* Mount Holly Water Co., 87 N. J. Law, 106, three children who had been using this water became ill with typhoid fever. Judgment was for plaintiff, higher Court inferring that water was polluted. In HAMILTON *v.* Madison Water Co., 116 Me. 157, it was shown that typhoid epidemic had been caused by sewage pollution. Court held water company liable. In HAYES *v.* Torrington Water Co., 88 Conn. 609, typhoid epidemic had broken out and 97 percent of cases had used this water containing colon bacilli: company was held liable. In PENNSYLVANIA R. Co. *v.* Lincoln Trust Co., 91 Ind. App. 28. City was held liable when during typhoid epidemic water was found to contain many colon bacilli. In RITTERBUSCH *v.* City of Pittsburg, 205 Cal. 84, Court held city liable. City water system had, owing to negligence, permitted unchlorinated water to be served through its mains. In WIESNER *v.* City of Alban, 224 App. Div. 239, typhoid epidemic had been caused by impure city water. Presence of colon bacilli was held to incriminate water. In STUBBS *v.* City of Rochester, 226 N. Y. 516, Court held city liable. Plaintiff and 60 neighbors had drunk the water and suffered from typhoid. In all but one of foregoing cases, epidemics were in evidence: in absence of epidemic, presumption favors exoneration of water. In GOSSER *v.* Ohio Valley Water Co., 244 Pa. 59, man engaged in traveling business had lived, eaten, and drunk at various places and died of typhoid. Suit filed against water company failed in higher Court. **Industrial Firm Liable For Water Pollution.** Courts have held manufacturing company that contaminates a stream to be liable in damages. Municipality amerced in damages owing to polluted water may often recover from firm responsible for pollution. In Latonia Refining Corporation *v.* DUSING, 55 S. W. (2d) 23, fact that pollution is essential to operation is not held to affect liability for resultant damages. **Preventing Water Pollution is Secondary.** Unless great injury may otherwise result, or unless need for purity be considered an emergency, city officials cannot use public money to remedy water pollution, if such money is required for payment of presently due valid debts. In State *v.* City of Van Wert, 184 N. E. 12, state health director filed suit to compel city to comply with order issued by health commissioner requiring city to install sewage disposal plant to prevent pollution of stream by city sewage. Officials pleaded that failure to comply with order was requirement of funds to pay operating expenses of city and to retire debt on bonds previously issued. Court upheld refusal to expend money.—*R. E. Noble.*

Journal of the New England Water Works Association. 46: 2, June, 1932. **Chlorination for Special and Emergency Purposes.** J. D. McMahon. 121–132. During decade 1920–29, over three-quarters of water-borne illness reported in U. S., representing 40 percent of outbreaks, was due primarily not to pollution of raw water at its source, but to defects in system for collecting, treating, storing, and distributing for consumption. As an ally to liquid chlorine, chlorinated lime has been supplanted by true calcium hypochlorite, $Ca(OCl)_2$, placed on market in 1928. Its advantages are: higher available chlorine (63 percent or more) and greater solubility, stability, and uniformity. Calcium hypochlorite is used for stand-by service at Weston Reservoir of Boston Metropolitan District and for disinfecting small streams tributary to reservoir. It is efficient for small municipalities, for disinfection of new water mains, and for inhibiting algae growths in water reservoirs. **Water-Works Emergencies from the Health Standpoint.** Warren J. Scott. 133–137. Inadequacy of supply involves potential danger to health of community. Superintendents should be prepared with accurate records of stream flows, water consumption, gains and losses in storage, etc., to cope with water shortage. When emergency supplies became necessary, Connecticut Department of Health made hurried survey of watershed of proposed supply and provided temporarily a portable chlorinator. Consumers were advised to boil the water; but this did not relieve water works of legal responsibility. Increasing demand for improvement in appearance of drinking water and for elimination of taste and odor has led to more filtration plants and to control of algae by $CuSO_4$. Several instances of "medicinal or phenolic" taste were traced to tar on standpipes or on roads adjacent to reservoir. **Meeting Emergencies Resulting from Breaks in Water Mains.** Superintendents' Discussion. 138–142. Inspection of cast iron pipes from foundry to caulking, with careful laying, will prevent many breaks. Gates must be kept in good order and provision made for reporting and repairing breaks as soon as possible. Industrial plants using water for boiler purposes should be notified of a shut-down. **Construction Layouts and Location of Gates of Value in Emergencies.** Samuel H. MacKenzie. 143–145. Duplicate main lines with adequate blow-offs and gates have proven their value at Southington and Terryville, Conn. **Tuberculation of Mains as Affected by Bacteria.** H. G. Reddick and S. E. Linderman. 146–169. Specimens of tuberculations from old cast iron pipes in use at various points in East and in Chicago revealed on analysis, characteristics similar to those of bog ores and limonites, leading to logical assumption that tubercles also are caused by bacteria. *Leptothrix*, *Gallionella*, and *Spirophyllum* are well known agents in the formation of ocher beds and bog ores while *Crenothrix polyspora* multiplies with prodigious rapidity. In cultivating these bacteria, iron gelatin and iron agar were used and cultures were made from three pipes, one of them laid in Philadelphia in 1819. Three colonies were found. Tests with ferrous sulphate showed 90 percent of it collected by bacteria in 72 hours. All groups, including small organisms not identified, were able to grow on iron-free agar, developing in white, instead of reddish brown, colonies. At Falmouth, tubercles almost closing a pipe were formed by iron bacteria, although pipe was scarcely attacked. Addition of iron to water for coagulating purposes

may become detrimental to water service. No great corrosion is needful for tuberculation to set in. Minute bare spot where iron concentration is high will give bacteria a start and with organic food available, they increase rapidly, especially under slightly acid conditions. As tar coatings frequently exhibit pin-holes, favoring entrance of bacteria, bitumastic or cement linings are preferable. Cement, being alkaline, creates conditions antagonistic to tubercle formation. **Are Further Studies Needed on the Relation of Forests to the Water Supply in New England?** C. EDWARD BEHRE. 170–185. While relation of forests to floods, stream-flow, erosion, and water supply has been discussed, deductions drawn have never been subjected to measurement, or to experimental proof. LEAVITT amendment to SWEENEY-MCNARY Forest Research Act authorizes nation-wide study of forests in these respects. Appropriations will be made for specific projects. Water resources question is of vital importance to New England because of dense population and numerous cities dependent upon surface supplies. Adequate methods for calculating quantity, regularity, and quality of stream-flow are essential. **Water Works in Cuba.** JOHN F. PIERCE. 184–195. Of 200 rivers in Cuba less than 10 can furnish enough water throughout the year for municipal requirements; but ground water is abundant, springs, wells, and subterranean rivers being common. Inadequacy of water is due mainly to porous nature of the limestone, which makes impounding difficult. Some towns use cistern water; water peddlers are common; and, in some cases, water must be transported 25 miles in tank cars. At Santiago de Cuba, annual rainfall is 46 inches, of which 75 percent falls between May and October. Water laws date from Royal Decree emanating from Madrid in 1891. Of 37 aqueducts reported, 25 are privately owned. **Accounting for Water Districts.** JAMES W. GRAHAM. 196–200. In 1899, Harry Eaton, of Waterville, conceived the idea that Maine laws, restricting bonds on municipal plant to 5 percent of the valuation, would not apply to water district, composed of several municipalities. Based upon this principle, water districts were created. At present, all water utilities use uniform classification of accounts prepared by Public Utilities Commission of Maine. **Unaccounted-For Water in Norwood, Mass.** C. A. BINGHAM. 201–203. Confronted by charge that 33 percent of water was unaccounted for, town manager of Norwood authorized Pitometer survey which accounted for 81.8 percent of water pumped. System is 100 percent metered, including withdrawals from hydrants except in cases of fire. **The Nashua Fire of May 4, 1930.** WILLIAM F. SULLIVAN. 204–213. Worst fire in history of Nashua, N. H., started on long, wooden railroad bridge from whence sparks were carried by 54-mile gale to lumber yards and dwellings. Wood-shingled roofs offered exposed inflammable material which hastened spread of flames. With nineteen neighboring communities sending fire-fighting equipment, draught was enormous and, in addition, there was loss from abandoned hydrants and 206 bleeding services with a total cross sectional area of 231.59 square inches. Nashua has reserve of 50 m.g. in supply pond and, in addition, 650 m.g. of impounded surface water of excellent quality. The 6- and 8-m.g.d. Snow triple expansion pumps were operated together for six hours. Total pumpage was 6.4 m.g., of which 5.25 went into fire during nineteen-hour period. Pressure range was from 52 to 32 lbs.,

with average of 41. **Effect of Present Economic Conditions in Massachusetts upon Water Supplies.** Arthur D. Weston. 214–216. Survey of 14 representative cities in Massachusetts showed practically no curtailment in water works activity. Of these 14 percent predicted increased construction for 1932, and 65 percent, usual amount of work. Three cities anticipated a slight decrease and one a serious reduction. **Relief of Unemployment at Leominster by Water Works Activities.** W. Guy Classon. 217–218. In 1931, Leominster, Mass., Water Board was authorized by Legislature to borrow $100,000 for reservoir improvements and to issue $25,000 in bonds for 16-inch pipe lines. As many resident unemployed as possible were given work and, despite their inexperience, results were satisfactory. **Proposed American Tentative Standard on Cement-Mortar Lining for Cast-Iron Pipe and Fittings.** 224–228. Proposed standard has been approved by American Gas Association and recommended for approval by Committee on Water Works Practice of A. W. W. A. It is still subject to change before submission to American Standards Association for approval. New standards provide for thicker cement linings to insure longer life, to prevent tuberculation, and to maintain carrying capacities.—*T. F. Donahue.*

Journal of the New England Water Works Association. 46: 3, September, 1932. **American and English Water Works Practice: Random Impressions of an English Chemist.** John T. Calvert. 229–240. Water consumption in England is low as compared with that in American cities, averaging 40 to 50 gallons daily per capita. Moderate temperature and 24 inches of rainfall evenly distributed throughout year prevent floods, drought, and excessive turbidity. English were pioneers in installation of slow sand filters which are now being replaced with rapid sand type according as economic conditions permit. Increasing pollution of Thames River, which supplies 60 percent of London's water, has led to proposed longer retention periods in artificial reservoirs and even to proposed rejection of Thames in favor of new supply from Welsh Hills involving long cross-country aqueduct. Water softening is practiced only by industries requiring it and water reclamation, which is necessary in National Park and at Los Los Angeles, is unheard of in England. **Measures Adopted for the Control of Tastes and Odors Due to the Development of Microscopic Organisms in Spot Pond Reservoir, Boston Metropolitan District.** Samuel E. Killam. 241–251. During 1931, growth of *Synura* reached concentration of 7,500 areal standard units per cc. in Spot Pond Reservoir and disappeared in late October to be followed by *Uroglenopsis,* in amounts varying from 1,000 to 3,500 units. Oily, fishy odor in water caused numerous complaints. Ammonia-chlorine treatment brought some improvement, but failed to eliminate taste at ends of distribution system. With spring thaw, copper sulfate was applied, at rate of 2.6 pounds per m.g. Taste diminished and complaints ceased about one week after application. During taste period, many private wells, springs, etc., were put into service regardless of hygienic considerations. **The Nashua Fire of May 4, 1930. Appendix.** William F. Sullivan. 252–263. Photographs, maps, pressure charts, and other interesting data on fire described in June, 1932 issue of Journal N. E. W. W. A. **The Use of Water in Gas-Operated Refrigerators.** Superin-

tendents' Discussion, December 9, 1931. 264–268. Loss of revenue on water used, but not recorded, by gas-operated refrigerators has led several cities, including New York, Chicago, and St. Louis, to make a flat annual water charge of $2.50 for each one installed. Where meters are in service, water might be measured by installing flush tank which can be periodically filled at a rate of flow sufficiently great to register on meter. **Difficulties with Water Bill Collections during the Depression.** Superintendents' Discussion, May 11, 1932. 269–271. At Danvers, Mass., delinquent customers are permitted to work off water bills on reforestation project at rate of 50 cents an hour and are allowed an equivalent amount of extra time for compensation in cash. As most companies report an increase in water losses, this method is considered superior to carrying the account indefinitely, or to applying a lien. **A Comparison of Methods for Determining the Areal Mean Precipitation on Drainage Areas.** JOHN B. BELKNAP. 272–282. Usual method of determining mean precipitation of a drainage basin is to take direct average (arithmetical mean) of records of rainfall stations lying within the basin. THIESSEN method is based upon principle that rainfall record of any station shall be accounted only to that portion of drainage area lying nearer to that station than to any other. A third method, that of drawing iso-hyetal lines, or lines of equal rainfall, is too laborious to be practicable. Comparative study of three drainage areas, using direct and Thiessen methods, show a variation insufficient to warrant additional work involved in THIESSEN method. **An Automatic Transfer Fermentation Tube Battery for Determination of B. Coli in Water.** WILLIAM FIRTH WELLS. 283–287. Double planting, as proposed by JORDAN, involves one of two procedures: lactose tubes, inoculated with water to be tested and showing gas after 48 hours of incubation, are transferred to brilliant-green-lactose-bile, where appearance of gas after a second 48 hours serves as confirmation test; or lactose broth and brilliant-green-lactose-bile are inoculated in parallel and appearance of 10 percent, or more, gas in brilliant-green tubes warrants recording sample as positive. Without discussing relative merits of JORDAN's procedure and Standard Methods, author introduces an automatic transfer device, consisting of twin battery of fermentation tubes connected by capillary siphon, to simplify technique of double planting. Capillary siphon serves to inoculate secondary tube (brilliant-green-lactose-bile) just as soon as gas appears in primary tube (lactose broth). Batteries in covered copper boxes with open side walls eliminate cotton plugs, racks, and baskets and simplify individual tests for B. Coli. **Domestic Flow as Affecting Meter Registration and Water Revenue. A Preliminary Study.** H. W. GRISWOLD and W. A. GENTNER. 288–311. Accepted specification for disk meters calls for registration of not less than 98 percent nor more than 102 percent when tested "within normal test-flow limits." To determine limit of endurance, three $\frac{5}{8}$-inch meters were connected in series on supply-line to Sloan flush valve operating automatically at rate of 10 four-second flushes per minute, or approximately 20 g.p.m. After 400,000 cubic feet had thus been passed, another 325,000 cubic feet were passed in continuous flow. Two of units tested measured up to new meter requirements and all three held up exceptionally well. Hartford, Conn., water system has been fully metered tince 1904. Many interesting surveys

are cited. In houses with flush tank toilets, from 7 to 12 percent of water consumed is unrecorded; while with flushometer toilets, loss is but from 5 to 8 percent. **Powdered Activated Carbon in Water Purification.** F. E. Stuart. 312–315. Besides removing tastes and odors, powdered activated carbon, applied ahead of, or together with, coagulant, stimulates rapid and effective floc formation, prevents decomposition of old sludge, reduces chlorine demand by absorbing and removing soluble organic matter and decomposition products, and when deposited on filter bed, removes chlorine. Proper dosage is from 1 to 3 p.p.m., depending upon condition of water and point of application.—*T. F. Donahue.*

Proceedings, Lake Michigan Sanitation Congress. 4: 1, January, 1928. 48 pages. **Greater Water Supply Projects in Chicago Metropolitan District Plan of the Greater Chicago Lake Water Co.** Walter M. Smith. 19–31. Types of water supply of Chicago and outlying cities within 28-mile radius are described. Proposal is to furnish filtered Lake Michigan Water to all towns and cities in Metropolitan District, including approximately 100 municipalities. **Pollution by Vessels.** Isador Mendelsohn. 44–48. January 1914 Progress Report of International Joint Commission on Pollution of Boundary Waters pointed out seriousness of pollution by (1) raw sewage, garbage, etc., discharged from toilet and other outlets; (2) water ballast; (3) dredged material from scows; and (4) oil waste. U. S. Public Health Service arranged with owners of vessels entering Cleveland and Chicago harbors, in 1921 and 1926 respectively, to lock all public toilets while in harbor and in vicinity of intakes and beaches. Consequently many vessels installed sewage retention tanks and hypochlorite filters for sterilizing sewage effluent. Sanitary control of scow and hydraulic fill operations at Chicago is described. Problem of sewage and water ballast disposal from lake vessels without involving public health menace is still unsolved and will become more serious with opening of lake ports to foreign shipping.—*R. E. Noble.*

Proceedings, Lake Michigan Sanitation Congress. 4: 2, April, 1928, 47 pages. **Semi-Annual Report, Division of Sanitary Engineering, Illinois State Dept. of Health.** Harry F. Ferguson. 21–26. **Indiana's Campaign for Sanitation.** Lewis S. Finch. 27–31.—*R. E. Noble.*

Proceedings, Lake Michigan Sanitation Congress. 4: 3, July, 1928, 80 pages. **Effect of Industrial Wastes on Filtration.** John R. Baylis. 4–10. *Wastes that Interfere with the Filtration Process.* Troubles from industrial waste will vary with its concentration and with time elapsed since its introduction and may include tastes and odors, increased chemical dosage, increased hardness, increased corrosiveness, or unsuitability for some specific use. Twenty-nine types of wastes are listed, chiefly putrescible organic, or taste producing. *Standards for Drinking Water.* Aim of all water treatment plants throughout United States is to average less than 1 *B. coli* per 1000 cc. throughout year. Plants falling short of this figure will usually have periods in which Treasury standard is not met. No standard exists for turbidity of finished water, but it does not exceed 0.2 in best practice. *Charac-*

ter of Pollution Determines Treatment. Bacterial Efficiencies of Filter Plants (without Chlorination). Efficiency is variable and dependent upon character of water and quantity of coagulant. In waters of low turbidity, moderate pollution, and treated with less than 1 grain coagulant per gallon, efficiency is usually less than 90 percent, especially for *B. coli* reduction. With fairly turbid water, 95 percent efficiency is possible. Clear Chicago water treated with aluminum sulfate to yield effluent of 0.2 turbidity will lose 75 percent of its *B. coli*: so that to average not over 1 *B. coli* per 1000 cc., raw water would have to average not over 4 per 1000 cc., or less than Treasury standard. Increased coagulant dosage increases cost. One grain per gallon aluminum sulphate costing 1 cent per pound would amount to over $1000 per day for Chicago. Chicago raw water pollution has passed the point where filtration alone, using minimum amount of coagulant to clarify, will produce safe water all the time. *Lake Water is Now (1927) Polluted Too Highly at Points for Filter Plants to Handle. Chicago Can Handle By Filtration Most Pollution Now Entering Lake.* More chlorine or coagulant than theoretically necessary would be required. However, taste trouble from industrial wastes containing phenol cannot be eliminated by filtration alone. Chicago could, with excess lime treatment, handle present pollution without chlorine, occasional extreme phenol pollution excepted. *Who Should Pay Cost of Eliminating Pollution?* Cost of reducing pollution to point where efficiently designed filtration plants can handle load should be borne by those responsible for pollution, whether city sewage, or industrial wastes. **The Disposal of Industrial Wastes.** E. S. CHASE. 10–13. **Solution of Phenol Troubles in the West Virginia-Pennsylvania Area Along the Monongehela River.** R. E. TISDALE. 14–16. By co-operative arrangement, 97 percent of phenol was removed from by-product coke plant effluent by benzol absorption method. **Stream Pollution and Industrial Waste Investigations of the U. S. Public Health Service.** H. R. CROHURST. 25–29. Briefly outlines development of U. S. P. H. S. since 1798. Studies included strawboard and wastes.—*R. E. Noble.*

Formation of Floc by Ferric Coagulants. EDWARD BARTOW, A. P. BLACK and WALTER E. SANSBURY. Ind. Eng. Chem., 25: 8, 898–903, 1933. Using 1.6 g.p.g. of ferric sufate and adjusting pH with sodium hydroxide or sodium bicarbonate, coagulation occurred at pH 5.0 to 7.0, most rapidly at pH 6.1 to 6.4. With 25 to 250 p.p.m. of sulfate (as sodium sulfate) added, zone of rapid flocculation was broadened on acid side as far as pH 3.9, effect of 25 p.p.m. being almost as great as that of 250 p.p.m.: from pH 7.0 to 8.5 flocculation time increased; but decreased again from pH 8.5 to 9.6. Effect of 25 to 250 p.p.m. of chloride (as sodium chloride) was similar, but less marked on acid side, and, with high chloride dosages, more marked on alkaline side. Chlorinated copperas as coagulant gave similar results. Shift can possibly be ascribed to reversal of sign of colloidal floc particles from positive below pH 7.0, where coagulation is affected by sulfate and chloride anions, to negative above pH 7.0, where it is influenced by sodium cations. In corroboration, solutions containing 5 p.p.m. of chloride as calcium chloride coagulated more rapidly than those with 50 p.p.m. of chloride as sodium chloride above

pH 7.0, and calcium hydroxide was much more effective than sodium hydroxide. If ferric floc particles are negatively charged at higher pH values, difficulty in removing negative color colloid in this range can be explained. At pH 3.5 to 9.4 amount of iron remaining in solution was correlated with time of floc formation.—*Selma Gottlieb.*

Chloride and Sulfate in Rain Water. W. D. Collins and K. T. Williams. Ind. Eng. Chem., 25: 8, 944–5, 1933. Results suggest that greater part of rain falling in United States contains less than 0.3 p.p.m. of chloride and not over 2 p.p.m. of sulfate.—*Selma Gottlieb.*

The Effect of the Reaction of the Medium on the Characteristics of Bacteria. I. General Presentation of the Problem, and Results Obtained with Bacillus Coli-Communior, Salmonella Enteritidis, and Pseudomonas Pyocyanea. Esther Wagner Stearn and Allen E. Stearn. Jour. Bact., 26: 1, 9–36, 1933. Results of previous workers are tabulated and discussed. Cultures were transferred repeatedly in unbuffered beef infusion broth at pH values from 5.15 to 8.4 and then grown on agar of same pH. Decided differences in appearance of cultures, morphology, and motility were noted with change in pH. Differences in cultural characteristics were slight. When cultures were grown in neutral broth or agar after 36 transplants in phosphate-buffered broth at various pH values, many of differences disappeared, though there remained some indication of more than temporary adaptation. Comprehensive bibliography is appended. *Selma Gottlieb.*

A Review of Fluorine and Its Physiological Effects. F. J. McClure. Physiological Reviews, 13: 3, 277–300, 1933. With bibliography of 127 titles. —*Selma Gottlieb.*

NEW BOOKS

A Study of the Pollution and Natural Purification of the Upper Mississippi River. Surveys and Laboratory Studies. H. R. Crohurst. Public Health Bulletin, 203, December, 1932. 113 pages. Sewage and industrial wastes from metropolitan area of Minneapolis and St. Paul create objectionable conditions in upper Mississippi River between Minneapolis and Hastings during summer months of low stream flow. Point of maximum pollution varies, usually occurs near Hastings, about 20 miles, or approximately 15 hours flow under low water conditions, below lowest sewer outlets of Twin Cities. This compares with similar maxima noted in Ohio River at from 10 to 15 hours below Cincinnati sewers, and in Illinois River at from 10 to 25 hours below Lockport. Chemical data obtained suggest that, in polluted streams having long period of ice cover, oxygen conditions may become more critical and effects of pollution be noticeable considerably farther downstream toward end of winter, rather than in summer. Oxygen requirement (5-day B. O. D.) increases to a maximum usually about Hastings, decreasing then as far as outlet of Lake Pepin, much organic matter being oxidized during long period of flow through lake. From Lake Pepin to Winona, although additional pollution is not great, yet oxygen requirement frequently increases, especially when Mississippi is low and when

Chippewa River, entering below Lake Pepin, is high. Reasons for this increase are given. Oxygen balance, or ratio of dissolved oxygen to oxygen demand, shows progressive decrease downstream to Hastings, at which point it begins to increase, except during season of ice-cover when, re-aëration being retarded, recovery may begin at points considerably farther downstream. Below Lake Pepin, secondary decrease in oxygen balance may occur. Draft on oxygen in pool at Minneapolis in summer is greater than would be expected from sewered population, owing to sludge accumulations during cold season, when biological activity is low. In lower section, where little actual sewage pollution is discharged, similar phenomenon occurs. Bacteria show progressive increase in numbers from above Minneapolis to Hastings, and then decrease. In lower section, between Lake Pepin and Winona, there is at times an unexpected increase, not accounted for by additional pollution. Similar increase was noted in Illinois River below Kankakee. Disturbance of biological conditions as result of dilution is one possible explanation. Increase in bacterial content of streams during a considerable time after sewage has been added has been consistently observed throughout stream-pollution studies. Indicated per capita contribution of bacteria from sewered population of Twin City metropolitan area is lower than that from metropolitan areas on Ohio and Illinois Rivers, Pittsburgh and Wheeling areas excepted. Indicated bacterial purification between point of maximum pollution and outlet of Lake Pepin varies with season from 97 to 98.5 percent. Rate of disappearance of *B. coli* organisms in summer between Hastings and inlet of Lake Pepin is greater than those of 20°C. and 37°C. agar organisms, which are practically the same. In winter, rates follow order *B. coli* >37°C. organisms >20°C. organisms. Summer rates are from 1.1 to 4.3 time as great as winter rates, much as was seen in case of Ohio and Illinois Rivers. Lake Pepin, however, introduces conditions not entirely comparable with those prevailing in Ohio and Illinois Rivers, being intermediate between them. Data suggest that initial concentration of bacteria may influence to some extent rate of bacterial disappearance. Of special significance in upper Mississippi is effect of the ice-cover, which, by preventing replenishment from atmosphere of oxygen deficiency, greatly retards the processes of self-purification. Bulletin includes 7 sections, 43 tables, and 11 figures.—*R. E. Noble.*

Proceedings of the Tenth Annual Short School. Texas Public Health Association, November 7–11, 1932. Following papers are of water works interest. **The Detection of a Typhoid Carrier.** S. W. BOHLS. 10–12. Methods employed by Texas State Department of Health for detection of carriers, with particular reference to transportation of specimens, for which purpose brilliant green medium is preferred, are outlined. Typhoid outbreaks reported in literature attributed to carriers are discussed briefly. One carrier has been reported who had had typhoid fever 55 years previously. It is known that typhoid bacilli may live in unsterilized water for 2–3 weeks and may be borne in streams at least 85 miles, maintaining their vitality for 5 days. Fifteen references. **Practical Methods for Biochemical Oxygen Demand Determinations.** P. J. ALWIN ZELLER. 23–4. For benefit of plant

operators who may be confused by the many methods and modifications for biochemical oxygen demand determinations appearing in literature, procedure is outlined by means of which reliable results may be obtained without the use of expensive and elaborate apparatus. **Method for Demonstrating the Coli-Aerogenes Group as Used in the State Hygienic Laboratories.** JOHN H. BREWER. 28–30. Procedure employed at the Texas State Laboratories in routine *B. coli* tests, which is essentially the same as that prescribed in Standard Methods, is described. Time-saving modifications have been developed, several of which are outlined. Instead of fishing from eosin methylene blue plates to an agar slant and a lactose broth tube, a single colony is selected and a combination bromthymol blue lactose agar slant and stab made, acid formation being indicated by yellow color and gas formation by bubbles. Examination of over 7000 samples showed 56 percent of shallow wells, 73 percent of springs, 86 percent of deep wells, and 84 percent of impounded surface waters to be potable.—*R. E. Thompson.*

Barrages et Geologie (Dams and Geology). MAURICE LUGEON. 138 pp., 104 photos and figs. Dunod; Paris, 1933. Good résumé of application of geological science to selection of dam site, preparation of foundation, and maintenance both of structure and of reservoir.—*R. DeL. French.*

Proceedings Eighth Annual Meeting Kentucky-Tennessee Section of the American Water Works Association, Louisville, Kentucky, February 9-11, 1933. Pp. 149. **Distribution Systems.** D. E. DAVIS. 6–16. Complete plans of distribution system are fundamental essentials. Valves should be regularly inspected. Direction of opening should be uniform. Hydrants should be regularly inspected, drains cleared, seats kept tight, freezing prevented. Mains should be examined for corrosion, deposition, and tuberculation. Regular flushing schedule should be instituted. Waste surveys should be prosecuted constantly by meter readers and maintenance crews. Plans for extension should be made long in advance. Population and industrial area trends should be studied and systems reinforced as need is indicated. Storage should be provided to lighten peak loads on pumps. Quality of water and its effect upon mains, services, and consumers' fixtures should be studied and defects remedied. Discussions of this paper brought out many examples illustrative of dangerous conditions. **Water Rate Schedules.** F. E. BECK. 16–23. Water rates must be reasonable, both absolutely and relatively, and when taken as a whole, must yield enough to cover operating expenses, including depreciation, interest, and profit on the fair value of the property used and useful in providing the service. Discussion points out variable character of services rendered and different charges to be made therefor. **Obsolescent Water Works and their Rehabilitation.** C. N. HARRUB. 24–35. Examples of antiquated and rundown water works plants which have menaced consumers, or resulted in unnecessary waste of funds, and of means taken to remedy these conditions. **Iron Removal.** WELLINGTON DONALDSON. 35–42. Soluble iron in water results in discoloration of water containers, plumbing fixtures, and laundry. Quality of beverages prepared with such water and of vegetables cooked therein is impaired. Content as small as 0.3 part per

million produces troublesome effects. Effective means for iron removal are aëration, contact beds, and filters. Description of iron removal at Memphis plant. Methods used for treating well waters carrying as much as 75 parts per million of iron were discussed. **Efficiency and Limitations of Water Purification Processes.** H. W. STREETER. 42–49. Results of studies during 1915–16 and 1923–29 on municipal water purification systems along the Ohio and other rivers and on the Great Lakes and on operation of experimental plants indicate following maximum numbers of raw water *B. coli* corresponding to a quality of effluent falling within limit of present U. S. Treasury Department standard (*B. coli* not exceeding 1.0 per 100 cc.) for various degrees of treatment:

	LIMITING RAW WATER B. COLI INDEX PER 100 CC. (ROUND NUMBERS)	
	Ohio River	Great Lakes
(1) Chlorination alone	80	50
(2) Coagulation, sedimentation and rapid sand filtration (without chlorination)	80	60
(3) Same as (2) with prechlorination	3,500	*
(4) Same as (2) with postchlorination	6,000	4,500
(5) Same as (2) with both prechlorination and postchlorination	20,000	*
(6) Same as (4) with double-stage sedimentation (relatively long sedimentation period)	60,000	*

* No observations.

Coagulation. M. E. FLENTJE. 49–55. Conduits, if of sufficient length, with sufficiently high velocity of flow, are efficient mixing devices. Pumps, especially of centrifugal type, are effective. Baffled chambers with velocity from 0.6 to 2.0 feet per second and with retention periods from 3 to 90 minutes are in general use. Mechanical agitation at rates from 0.3 to 2.0 feet per second peripheral speed are coming into increasing use. Hydraulic pump supplemented by pool with velocity of flow from 0.75 to 1.0 foot per second provides good floc within 5 minutes. Special devices such as flocculators are now being developed. As turbidity and hardness vary, types of treatment required will differ. **New Method of Flocculation.** FRANK BACHMANN. 55–62. Description of the Dorr flocculator, its advantages, operating costs, operating results, and economies. **Coagulation and Taste Control with Powdered Activated Carbon.** F. E. STUART. 62–72. Good description of activated carbon, of its methods and points of application, of its effectiveness in elimination of sludge decomposition and odor production in conjunction with prechlorination, in aiding coagulation, and in elimination of dead-end taste troubles; followed by examples of its use, and bibliography. **Factors Affecting Rate Making for Water Service.** E. E. BANKSON. 72–96. Analysis of costs of rendering water service and of fair rates to charge therefor, describing a method of computation and illustrated with tables and figures. **Checking**

Small Plant Operation by the State Department of Health in Ohio. F. H. Waring. 96–103. State law requires that municipality undertaking construction of water works must have plans approved by State Department of Health and work done under direction of competent engineers. Operation must be under supervision of competent men. Supervision by frequent visits of experienced water plant operator from nearby larger city is permitted. **Extensions to Subdivisions and Consumers Beyond City Limits. Round Table Discussion.** 103–104. In Louisville, subdivider outside of city pays entire cost of pipe lines required in subdivision. Water company furnishes consumers with water at rates. Subdivider may collect tapping charge until subdivision is annexed, or for maximum period of ten years. **Charges for Fire Hydrants and Sprinkling Systems. Round Table Discussion.** 104–108. Discussion brings out lack of any uniform basis for charges. Average charge for fire hydrant is about $50 each per year. **Covered and Open Reservoir for Treated Waters.** F. H. Waring. 109–113. Algae, microscopic organisms, dust, soot, leaves, flies, larvae, and danger to structure from freezing are all hazards incidental to open distribution reservoirs. Ohio Board of Health policy is to disapprove plans for open reservoirs. **Some Economic Aspects of Chlorination.** G. R. Kavenaugh. 113–121. In addition to protection of sanitary quality of water supplies, chlorination has been found to save cost of covering a reservoir; to save in filter operation by increasing length of runs and by decreasing wash water; to save cleaning costs of tanks, by sterilization of iron bacteria; to save costs of secondary treatment in sewage disposal; to eliminate odors; and to save cleaning of condenser tubes by control of slime formation. **Improving the Status of Water and Sewerage Systems as Public Utilities.** R. J. Morton. 122–130. Freedom from political interference, provision for adequate management and accounting, and legal provisions for assessment and collection of adequate rates should be guaranteed to the municipal public utility. Recent provisions for Government financing have promoted passage of enabling acts by states permitting establishment of water and sewerage systems on utility basis. These in turn have required that utility itself establish and show an accurate accounting of its operating condition. **Unaccounted for Water.** E. E. Jacobson, R. C. Wyatt. 130–133. Sources include: pump slip and poorly adapted pumps, unauthorized use of water, under-registering of meters, leakage from stand-pipes and reservoirs, house waste and fixture leakage, and underground leakage in distribution system. **Free Water to Public Buildings and Institutions.** John Chambers. 133–137. Unnecessary waste of water in institutions receiving water free is pointed out. Whereas seven parochial schools paying for water service use about 3 gallons per pupil per day, fifteen public schools furnished with free water use more than 15 gallons per pupil per day. **Aëration. Round Table Discussion.** 137–139. Aëration is effective for several purposes. Type of aëration employed should be suited to purpose intended. **How are Complaints Handled in the Water Office? Round Table Discussion.** 139–141. **Recent Pumping and Filtration Installations at the Nashville Plant.** R. L. Lawrence, Junior. 141–148. Description of installation of two 10-m.g.d. turbine-driven centrifugal high-lift pumping units in George Reyer station and of 42-m.g.d. rapid sand filtration plant.—*R. L. McNamee.*